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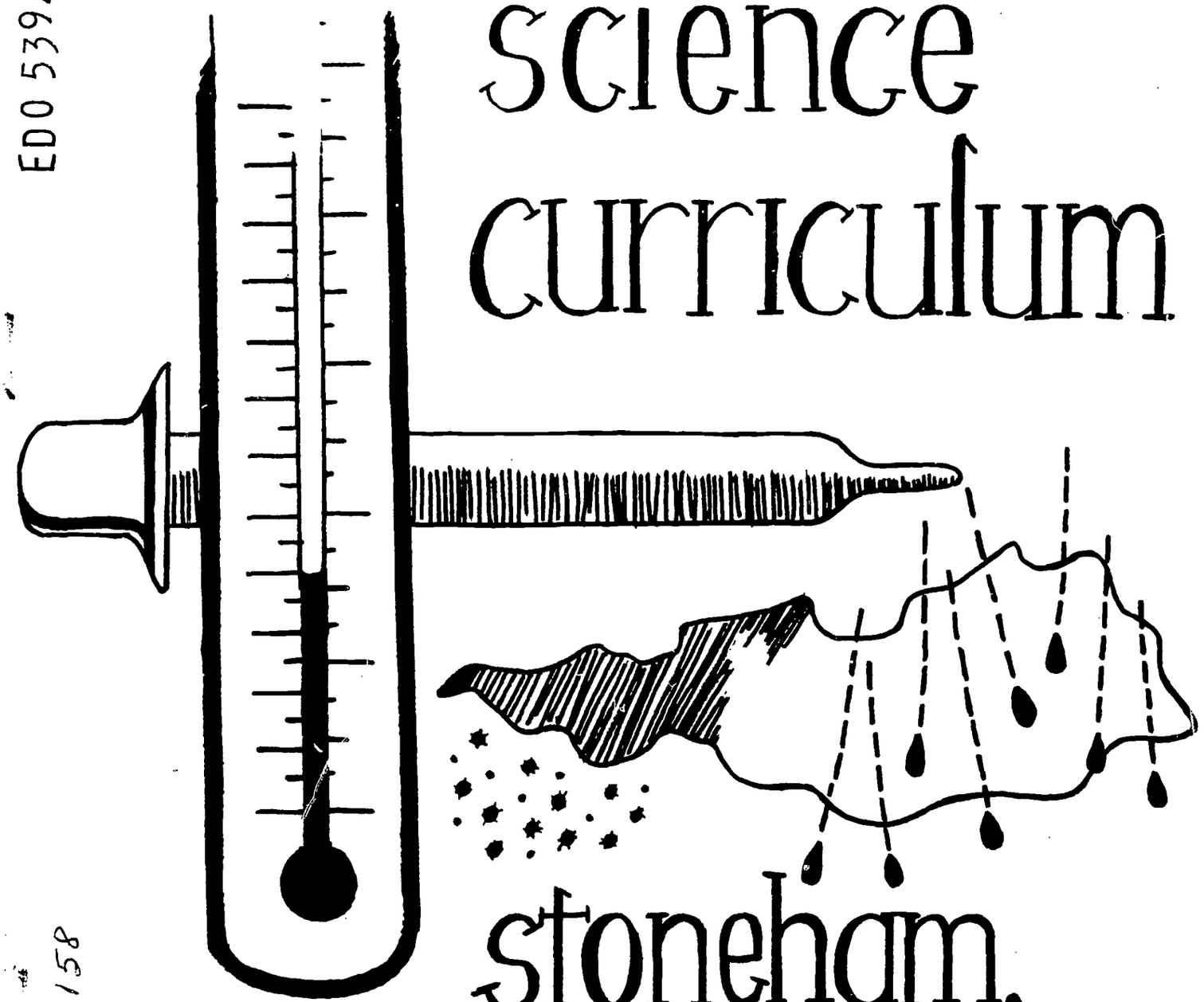
ABSTRACT

This is one of a set of curriculum guides for the Stoneham Elementary School Science Program (see SE 012 153 - SE 012 158). Each guide contains a chart illustrating the scope and sequence of the physical, life, and earth sciences introduced at each grade level. For each of the topics introduced at this grade level an overview of the topic, a list of concepts to be developed, motivating ideas, suggested activities to develop each concept, a reading list, a list of supplies needed, and examples of student work sheets are provided. In most activities the teacher is expected to involve all students in experimenting and applying scientific thinking. The topics covered in the grade six guide are: animal behavior, heredity, motion in the universe, light, photosynthesis, and ecological interrelationships and air pollution. (AL)

Transfer: ERIC/Science

Elementary science curriculum



grade 6

stoneham, mass.

STONEHAM PUBLIC SCHOOLS

STONEHAM, MASSACHUSETTS

ELEMENTARY SCIENCE CURRICULUM GUIDE

GRADE 6

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FOREWORD

These units were written as guides for the teaching of science. The activities suggested are given to assist the teacher in illustrating the given concepts. In some instances several activities, but only those which will best suit her class. In other cases the activities suggested follow a particular sequence which would encompass several days illustrating several related subconcepts along the way. It is not expected that the teacher stick rigidly to her curriculum guide. If deviating to include another concept, however, the teacher is advised to consult the other Stoneham Science Curriculum Guides to be certain that the concept is not introduced at another grade level. The teacher is encouraged to have reference materials in the classroom at all times for each unit.

Whenever possible, the teacher is expected to involve all the children in experimenting and encouraging application of the scientific method and thinking. This would involve the following skills:

1. to formulate hypothesis
2. to reason quantitatively
3. to evaluate critically
4. to draw conclusions
5. to select procedures
6. to define problems
7. to create charts and keep records
8. to use equipment effectively

It is intended that the teacher will adequately adopt this guide to her own class needs.

Susan Hopkins--------Grade 1
Judith Bowen---------Grade 2
Bette Littman--------Grade 3
Carol Bearse---------Grade 4
Joan Knipping--------Grade 5
Linda Young----------Grade 6 Co-Chairman
Mary White-----------Grade 6 Co-Chairman

November 1969

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STATEMENT OF PHILOSOPHY

We have all experienced the confusion of sorting out events that come at us, seemingly, haphazardly. We try to perceive the link, the relationship, that will make everything clear, that will help us decide. In fact, from the time we are born the main activity of our lives is trying to sense some order in our constantly changing world. Science is a tool that man uses to seek order. Modern science has evolved not only as a body of fact, but also as a logical approach to problem solving. In the elementary school this aspect of science should not be overlooked. The study of science should encourage growth in the ability to solve problems, as well as introduce a background of knowledge.

To achieve this goal the emphasis must shift away from the teaching of "facts" to the development of such abilities as: observation, collection of information, classification, formation of hypotheses, data interpretation, generalization, and prediction. Thus the process of learning becomes just as important as the information obtained.

This approach to teaching science transforms the classroom into a laboratory and the children into scientists working within it. The teacher provides enough orientation so that the children develop goals of their own, and guides them through concrete experiences that nurture both technique and knowledge of facts. There are many outcomes of a lesson: skills, facts, aroused curiosity, ideas, and discovery of new relationships. The pupils gain confidence in their own ability to learn, a process which will be valuable long after the facts are forgotten.

SCOPE AND SEQUENCE CHART

SCOPE AND SEQUENCE CHART

		GRADE 1	GRADE 2	GRADE 3
PHYSICAL	Chemistry	**Changes in Matter** melting freezing heating	**Changes in Matter** solid liquid gas molecular	
PHYSICAL	Physics	**Magnets** push & pull		**Magnets** attraction repulsion **Simple Machines** their uses relationships of applied force
LIFE	Human Body	**Growth** bones teeth nutrition health	**Growth** muscles skeletal structure emotions	
LIFE	Plants	**Reproduction** seeds bulbs spores regeneration	**Life Activities** structure classification seed plants non-seed plants	**Ecosystem** Pond Community
LIFE	Animals	**Classification** vertebrates	**Life Activities** life cycle insects brine shrimp	

GRADE 4	GRADE 5	GRADE 6
Molecular Theory matter molecules energy - relations		
Electricity static-current- production conductors **Sound** waves, vibration, pitch, reflection	**Heat** motion expansion-contraction conduction, convection insulators	**Light** photons- reflection- waves color
The Ear producing and hearing sounds	**Cellulor Organization** cells tissues organs	**Genetics** heredity genetic code dominant and recessive traits
		Photosynthesis leaf structure carbon cycle
Simple & Complex 5 basic life- processes- cellular structure classification		**Animal Behavior** inherited and learned **Ecology** balance in nature disbalance

(5)

SCOPE AND SEQUENCE CHART

	GRADE 1	GRADE 2	GRADE 3
Astronomy	**Earth - Sun - Moon** rotation day & night		**Solar System** orbits revolution seasonal change
Geology		**Fossils** dinosaurs fuels evolution	**Earth Composition** soil rock formation classification
Meteorology	**Changes in Weather** clouds		**Water Cycle** cloud formation precipitation weather prediction

E A R T H

SCOPE AND SEQUENCE CHART

GRADE 4	GRADE 5	GRADE 6
	Forces in Space centrifugal centripetal gravitational	Motion in Space movement of plants parallax, triangulation gallaxies-atomic energy
	Earth Changes surface interior Ocean Environment water food life exploration	
Influence on Man Air's ingredients of weather effects of weather		

ANIMAL BEHAVIOR

OVERVIEW

All animals must possess ways of detecting and reacting to what is occuring around them, if they are to survive. Animal Behavior is a unit dealing with these responses of animals to their environment.

The unit is developed through observation of, and experimentation with animals. For this reason, it is essential that animals be obtained for the classroom. A conscious effort has been made to include only those animals which are easily available, such as earthworms, mealworms, goldfish, flatworms and chameleons. Be sure to know the health and safety rules concerning the animals when introducing them to the pupils. The most readily available animal in the classroom of course, is homo sapiens, and many activities capitalize on this fact.

Observation, experimental procedures, record keeping, and the use of quantitative analysis to make accurate deduction, are emphasized in the unit. Records of all investigations should be kept. Some could be of an individual notebook nature, others could take the form of class charts. Record keeping clarifies thought, and sometimes points out what was not obvious at first encounter. In the appendix are suggested examples of form. The blocks provided in the "Results" section can be adapted for various situations.

Concepts to be Developed

1. All animals have some way of reacting to their environment.
2. All animals have some type of nervous system.
3. Simple animals have nerves and swellings which mark the meeting point of nerves.
4. Higher animals have a central nervous system, plus a control center - the brain.
5. A stimulus is any object or change in the physical environment that excites a sense organ.
6. Response is a reaction to stimuli.
7. Automatic reactions to stimuli are simple reflexes.
8. The manner in which the organism reacts to stimuli constitutes "behavior."
9. Behavior is inherited if it is a complicated series of acts which is exhibited without any previous training or practice.
10. Learning is any relatively permanent change in behavior as a result of past experience.
11. Conditioning is the learning of a particular response.
12. Reinforcement is the use of reward in learning.
13. Habits are learned acts that have become automatic.
14. Practice helps form a habit.
15. A change in the structure of an animal that makes it easier for the animal to survive, is an adaptation.

Motivating Ideas

1. Introduce an animal into the classroom. Give no information about it, instead pose a number of questions relating to function and behavior. Perhaps one of the animals discussed in the unit could be used. This idea could also be adapted for use as a bulletin board.
2. Start a discussion with the question, "How much did you know when you were born?"

Investigations

1. ALL ANIMALS HAVE SOME WAY OF REACTING TO THEIR ENVIRONMENT.

Background: Most students have had experience with the reactions of higher animals, but may not realize that lower animals also have certain limited responses. Amoebas can sense chemicals in water. Planarians react to light. Earthworms react to several stimuli, even though they have no eyes, ears, or nose.

Have the children find worms, or order them from:

Brockton Worm Hatchery
Brockton, Mass.

Keep them in a large glass jar with soil, decaying leaves, sand, and cornmeal. Cover the outside of the jar with black construction paper.

Equipment: worms, lemon juice or vinegar, paper, flashlight, containers (for holding the worms during observation)

Activity: The students observe how earthworms react to changes in environment. It would probably be wise to instruct the class to keep the worms in the observation boxes.

1. touching anterier and posterior ends
2. paper dipped in lemon juice or vinegar brought near the anterior end
3. reaction to bright light

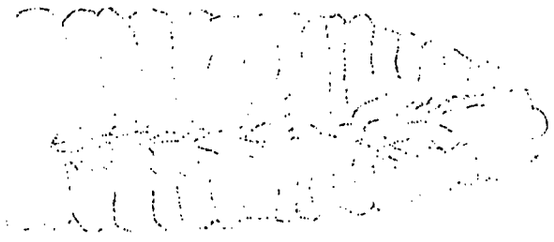
Extension:

1. Observe the reaction of moths to light. Investigate insect-repellent electric bulbs.
2. Investigate allergic reactions in humans.

2. MOST ANIMALS HAVE SOME TYPE OF NERVOUS SYSTEM.

3. MOST SIMPLE ANIMALS HAVE NERVES AND SWELLINGS WHICH MARK THE MEETING POINT OF NERVES.

Background:



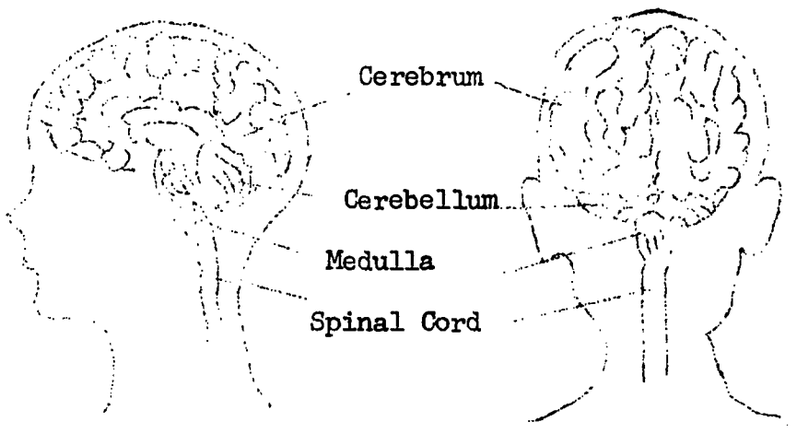
Anterior end

DISSECTING A WORM	A.	Equipment:	worms, pins, dissecting tray or small wood board, insect killing jar, dissecting knife or razor blade
		Activity:	Kill the worm, then pin down both ends. Starting with the posterior end, make a light cut the length of the worm. Pin open the sides of the worm. Use a magnifying glass to closely observe.
MAKING A REPLICA	B.	Equipment:	wire, beads and clay can be used
		Activity:	Use the diagram given in "Background" to guide the children in making their models.
		Extension:	1. Find out about the "eyespots" of a planaria (flatworms). 2. Find out what an ethologist does.

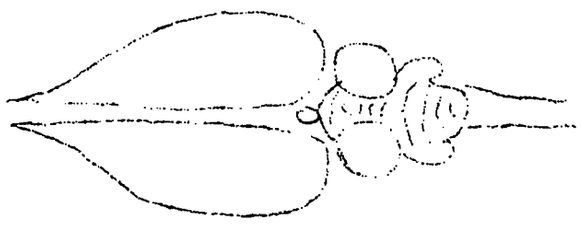
4. HIGHER ANIMALS HAVE A CENTRAL NERVOUS SYSTEM, PLUS A CONTROL CENTER - THE BRAIN.

A. Background: Pictures below.

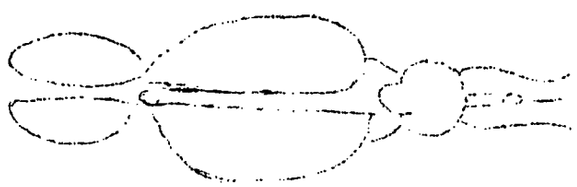
MAN



BIRD



FISH



Humans do not have the largest brains, but the cerebrum is highly developed. The cerebrum controls voluntary actions and interprets messages from the sense organs and nerves. The cerebrum determines how you react.

Equipment: Various reference books - encyclopedia and biology books plus materials for drawings.

RESEARCH NERVOUS SYSTEMS OF VERTEBRATES

Activity: Direct groups of children to do research on the comparative size of brains among several types of vertebrates. Also compare the abilities of the animals to control behavior. Emphasize that the complexity of nervous systems increases with the complexity of the animal.

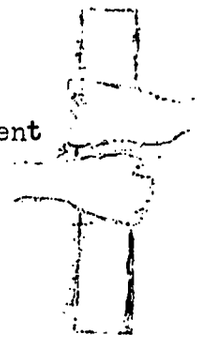
Extension:
1. Construct charts and drawings illustrating the results of the research.
2. Find out more about the nervous system of man.

B. Background: There is a certain time interval, reaction time, between stimulus and response. Nerve impulses average 400 yds. per sec.

Equipment: a yardstick, a clock with a second hand, or a stop watch

MEASURING REACTION TIMES

Activity: One child holds the yardstick, while the other has his hand directly below, but not touching.



Take Measurement

Note where the hand is positioned. The child holding the stick, drops it without warning.

Note where the yardstick is caught. The intervening distance is an indication of the reaction time.

Extension: Graph the results of the reaction time test from fastest to slowest.

5. A STIMULUS IS ANY OBJECT OR CHANGE IN THE PHYSICAL ENVIRONMENT THAT EXCITES A SENSE ORGAN.

6. RESPONSE IS A REACTION TO STIMULI.

Background: To study how scientists observe animal behavior in an orderly, accurate way, the students will conduct an investigation into the responses of mealworms to various stimuli. Three or four trails should be conducted for each investigation. All observations should be recorded. Emphasize that large numbers of results should be accumulated before a conclusion is made.

Mealworms are the larvae of adult beetles. They undergo metamorphosis from the larva to the adult stage in about five weeks. They can be obtained from pet shops, biological supply houses, or from the Brockton Worm Hatchery, Brockton, Mass., for a low price. A mealworm colony can be made from a jar filled with flour or breakfast cereal that is kept moist with apple pieces.

These activities will probably take a minimum of a week to complete.

Equipment: mealworms, plastic container for a colony, spoons for dispensing the worms, containers to be used for observation (plastic sandwich boxes are good), blotter, small dixie cups, black construction paper, shoe box, crayons, flour, apple, magnifying glass

OBSERVING MEALWORMS

Activities: A. Examine the mealworms. Direct the children to sketch the worms, being accurate as to body parts and the number of legs. Observe locomotion, and try to get the worm to back up. Encourage the students to try as many different methods as they can devise.

LIGHT AND DARK

B. Place four worms in the observation box, holding them together with an inverted dixie cup. Cover half the box with the black construction paper. Remove the dixie cup. Leave the container undisturbed for a few minutes. (Set a definite time period). Then observe where the mealworms are located. Record observations.

Repeat.

WET AND DRY

C. Tear the blotter in half. Wet one half and leave the other dry. Place them in the observation box. Place the worms in the box, holding them together with an inverted dixie cup. When ready, lift the cup and leave undisturbed for a few minutes. Then observe where the mealworms are located. Record observations.

Repeat.

TRACING A MEALWORM'S PATH

D. Put some food (flour or bran) in the center of a shoe box. Put a worm in the box at an arbitrary starting place, marked X. Trace the mealworm's path with a crayon to the food. Repeat, starting again at X, using a different color crayon. Have the students compare results.

Extension:

1. Combine the elements of activities 2 and 3. Plan experiments to investigate the mealworms' reactions to "wet and light" and "dry and dark."

2. Find out about the investigations of Karl von Frish, dealing with the behavior of bees.

7. AUTOMATIC REACTIONS TO STIMULI ARE SIMPLE REFLEXES.

Background: The automatic nervous system controls the action of your heart, digestive system and lungs. These chains of nerves are located along the spinal cord. We have no control over these involuntary actions.

BLINKING REFLEX

A. Equipment: a square pane of glass (you may want to put masking or electrical tape on the edges to prevent cuts), a small rubber ball

Activity: One child holds the glass in front of his eyes. Another gently throws the ball against the glass. The child holding the glass looks directly at the ball and tries not to blink. After a few trials the partners exchange places.

MUSCLE REFLEX

B. Equipment: none

Activity: The pupils work as partners. One crosses one leg over the other at the knee. His partner strikes just below the kneecap with the edge of the hand. This will not work if the child is contracting his leg muscles.

DILATION OF THE PUPIL OF THE EYE

C. Equipment: flashlight, mirror

Activity: The students work as partners. Darken the room for a few minutes. Have students observe the dilation of the pupils of the eyes of their partner. Shine a flashlight near the eyes and notice the change in size.

STARTLE REFLEX

D. Equipment: none

Activity: The teacher makes a sudden, loud noise behind a student. Even if the child is expecting the noise, there will be some reaction such as jerking of the head.

Extension:

1. Make a list of human reflexes. (Others include coughing, yawning, sneezing).

2. Test the reflexes of some other animal.

8. THE MANNER IN WHICH AN ORGANISM REACTS TO STIMULI CONSTITUTES "BEHAVIOR."

Background: Behavior can be simple or very complex. The following activity is a fairly simple reaction to change in environment. The more complex behavior of humans should also be discussed. Some starting points are given below.

	Stimulus	Response
1.	Recess time: the teacher blows a whistle.	The class lines up. (Try to elicit this from the students.)
2.	Your homework is not done, and you have no excuse.	There will probably be many interesting responses.

CHANGING GOLDFISH BEHAVIOR

Equipment: a goldfish, bowl, fish food, water, ice cubes.

Activity: Fill a bowl with water. Next day measure the temperature and deposit the goldfish. Observe the fish's eating habits for a few days. Then lower the temperature of the water 20° F by adding ice cubes. This should be done an hour before the fish is to be fed. Observe feeding habits and other behavior at this lower temperature for a few days. You will need to add ice cubes each day.

Note: Do not overfeed the fish. Skim off uneaten food. Don't forget to aerate the water.

Extension:

1. Investigate "pecking order" among chickens.
2. Many animals such as birds and monkeys, have a "territory" that they consider their own, and will defend. Find out more about this.

9. BEHAVIOR IS INHERITED IF IT IS A COMPLICATED SERIES OF ACTS WHICH IS EXHIBITED WITHOUT ANY PREVIOUS TRAINING OR PRACTICE.

Background: Inherited behavior could be called a complicated series of reflexes. Examples of this are: nest building in birds, the construction of spiders' webs, and the complicated society structure of ants, bees and wasps.

OBSERVING SOCIAL BEHAVIOR

Activity:

A. Show films and filmstrips illustrating inherited behavior.

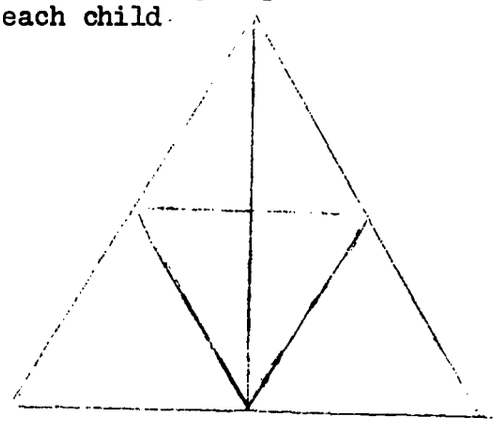
(list)

Honeybees	3 - 1 - F1
Wasps	3 - 1 - B7
Grasshoppers	3 - 1 - C3

B. Obtain an "ant farm" and have the students observe the ants' activities.

10. LEARNING IS ANY RELATIVELY PERMANENT CHANGE IN BEHAVIOR AS A RESULT OF PAST EXPERIENCE.

A. Equipment: six paper triangles that will fit together to make a large equilateral triangle, for each child

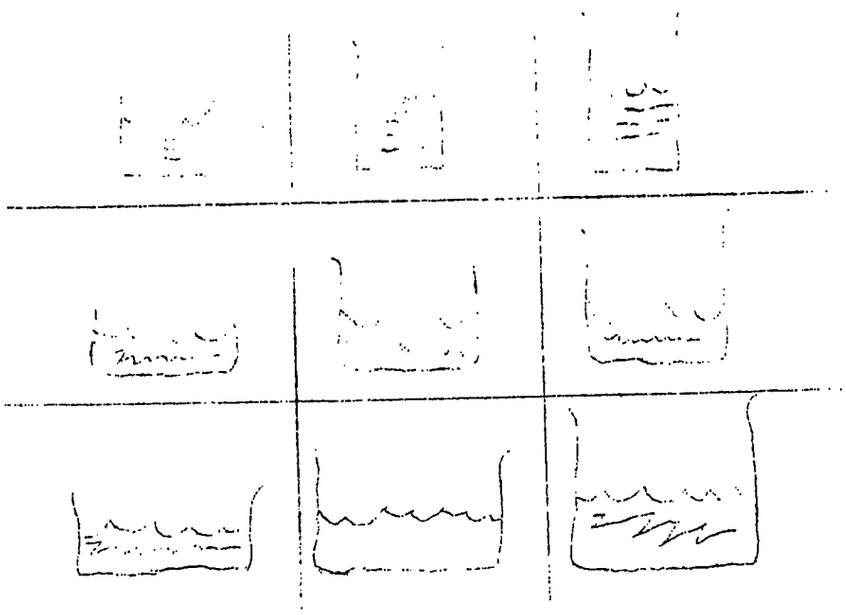


WORKING A PUZZLE

Activity: Distribute the triangles and allow the pupils time to reach a solution. Then elicit from them what previous learnings and experiences helped them solve the problem. (What an equilateral triangle is - symmetry - working other puzzles.)

B. Equipment: Chalk, paper, pencil

Activity: Draw the following pattern on the blackboard. Then erase

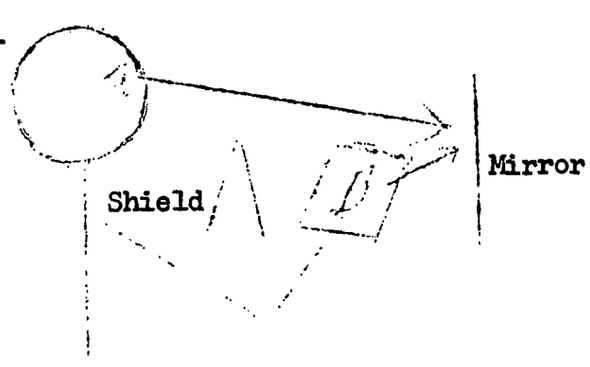


RE-CREATING A PATTERN

the pattern and direct the students to transpose the pattern on their paper backward and upside down. Then discuss what previous learnings and experiences helped them solve the problem. (What backward and upside down mean - the concept of progressive width and height.)

C. Equipment: mirror, cardboard, paper, pencil.

Activity:



LEARNING TO DRAW A STAR

Instruct the children to try to learn to draw a star by only watching their reflection in the mirror.

D. Equipment: planaria, battery, wire, flashlight, shallow dish, water

TRAINING A PLANARIA

Activity: Set up the dish, battery, and wires so that a shock will travel through the water. The planaria will react to the shock.

Flash the light simultaneously with the shock. After a few series of trials, determine if the planaria will contract with only the light as the stimulus.

11. CONDITIONING IS THE LEARNING OF A PARTICULAR RESPONSE.

12. REINFORCEMENT IS THE USE OF REWARD IN LEARNING.

Background: These two concepts should be introduced together, as they are related to each other.

In conditioning, a reward of some kind seems to tie the stimulus and response together. A new stimulus can be substituted by associating it with the original stimulus. (The classic experiment is Pavlov and his dogs.) An S-R bond is developed.

TRAINING A FISH

Equipment: an aquarium, fish, a flashlight, fish food.

Activity: Train a fish to respond to light. Keep the fish in a fairly dark place. Every time it is fed, flash a light. After a while, discontinue the food.

1. Inborn response: the fish responds to food.

2. Conditioning: association of the light and the food.

3. Conditioned response: the fish responds to the light.

Extension:

1. Conduct an experiment to find out how long the response will continue without the reward.

2. Further the experiment by training the fish only to respond to yellow light and not red light.

3. Plan an experiment to find out if the fish will respond to sound. Be sure that you separate the variable from the light response. Also find out if it is the sound or the vibration, the fish responds to.

4. Have the children apply what they have learned to the training of a a cat, dog, or other household pet.

13. HABITS ARE LEARNED ACTS THAT HAVE BECOME AUTOMATIC.

Background: We all develop many habits, some good some bad. As a result of practice such acts as tying shoes, brushing teeth, dressing in the morning, using a knife and fork, and riding a bicycle, have become automatic.

A. Equipment: lengths of rope for each child or group of children, clock with second hand or stopwatch

TYING KNOTS

Activity: Teach the children how to tie a knot--a square knot or bowline (consult your Girl Scout or Boy Scout manual). Have the children time themselves after one try, 5 tries and 10 tries. When they can tie it quickly, it has become a habit.

B. Equipment: lengths of rope, jump rope size

JUMPING ROPE

Activity: Practice jumping rope until it becomes an automatic act.

Note: It may be interesting to have the girls do activity A; the boys activity B.

Extension: Direct the class to complete the following habit formation survey. Compile the results.

Category	a	b	c
1. awakening	parents	yourself	alarm
2. awakening time	early	sufficient	late
3. dress	before breakfast	after breakfast	late
4. radio	while dressing	while eating	other
5. teeth	before breakfast	after breakfast	other
6. bath	before breakfast	after breakfast	other

	Category	a	b	c
7.	leave for school	early	on time	late
8.	study	at school	before supper	after supper
9.	radio	while studying	not while studying	other
10.	bed	set time	after study	various

14. FRACTICE HELPS FORM A HABIT.

THE VALUE OF PRACTICE

Equipment: paper, pencil, worksheet

Activity: Direct the children to draw a few circles, one inch in diameter. Evaluate the attempts. Then practice, using the sheet below.

Name_____

Investigation_____

Practice drawing perfect circles by tracing each circle about 10 times, using one sweep of the arm.

Then have the students try free hand circles again, to see if they have improved.

Extension:

1. Direct the students to write their names with the hand not normally used. Find out if penmanship improves after a few days of regular practice.

2. Apply what has been learned to study habits.

15. A CHANGE IN THE STRUCTURE OF AN ANIMAL THAT MAKES IT EASIER FOR THE ANIMAL TO SURVIVE, IS AN ADAPTION.

Background: A species becomes extinct because it cannot adapt to its environment. A modern day example of this is the ape. It has not adapted to dwindling tropical forests and food supplies. A giraffe is adapted for eating from the tops of trees, gazelles are adapted for eluding their predators, lions have teeth and claws that make it a good hunter. With changes in structure, different behaviors are possible for an animal, hence it survives.

OBSERVING THE ADAPTATION OF A CHAMELEON

Equipment: chameleon, green and brown paper

Activity: Place the chameleon on green & brown papers. Observe the change in color. Emphasize that this is an adaptation that has helped chameleons survive.

Extension:

1. Do research on the adaptations of other animals.
2. Find out more about adaptation by investigating the work of Charles Darwin, and Dr. L.S.B. Leakey.

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Jacobson, Willard J., et al. Investigating Science 6. American Book, 1965. Unit 3

Booklets

Denoyer-Geppert Co.
5235 Ravenswood Ave.
Chicago, Illinois

"Aquariums and Terrariums in Your Classroom." - Free

A. T. Root Co.
Medina, Ohio

"The City of Bees." - Free

Working Papers
Elementary Science Study
55 Chapel Street
Newton, Mass. 02160

"Earthworms." - $1.00

Science Service Desk
Webster Division
McGraw-Hill Book Co.
Manchester Rd.
Manchester, Missouri, 63011

"Mealworms." - $1.35

"Science Materials Catalog." - Free

Biological Supplies

Nasco
Fort Atkinson
Wisconsin 53538

Live Specimens:

- mealworms
- planaria
- ant farm
- bee hive

Insect Killing jar

Stansi Scientific Division
Fisher Scientific Co.
1231 North Honore St.
Chicago, Illinois 60622

Investigation #_____

Name:_____ Date_____

Problem:_____

_____

_____

Materials:_____

_____

_____

Procedure:_____

_____

_____

Results:

Mealworms	Number on Wet Blotter	Number on Dry Blotter
Trial 1	2	2
Trial 2	3	1
Trial 3	3	1
Trial 4	2	2
Total	10	6
Class Total	312	181

Conclusion: Meal worms seem to prefer wet places

_____

_____

Observation Sheet #_____

Name_____ Date_____

Description of Observation:_____

_____

_____

Sketch:

TIME	Description of Behavior

Summary:_____

_____

_____

THROUGH THE GENERATIONS

OVERVIEW

Through the Generations is a unit to be used as an introduction to genetics. There is little opportunity for first hand experiences in this area, so emphasis has been put on the skills of observation, data interpretation, deduction, and prediction. The students will trace a family tree, make a simplified model of DNA, take a survey, and learn about gentic ratios through Mendel's Laws. You will need to send away for PTC paper and irradiated seeds before beginning the unit. See the appendix for where to write.

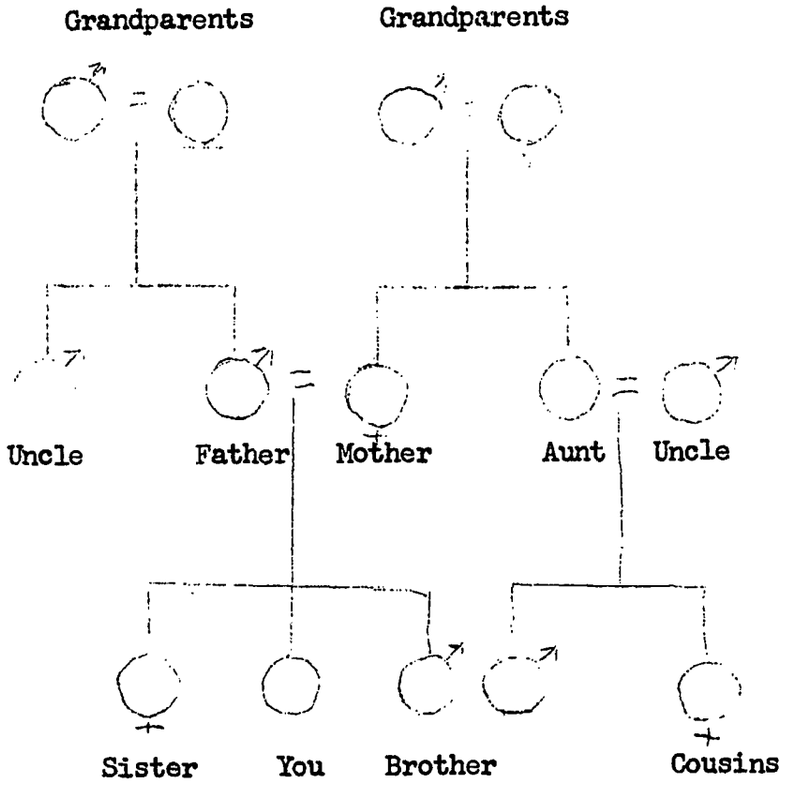
Concepts to be Developed

1. The resemblance of living things to their parents is called heredity.
2. Characteristics are passed on through the generations by chromosomes, which are in the cells of all living things.
3. The development of a trait is controlled by environment.
4. The study of heredity is genetics.
5. A trait that always appears in off spring if carried in the cells is called dominant.
6. Traits that appear only when dominant genes are not present are called recessive.
7. A mutation is a new hereditary characteristic resulting from a change in the genes.
8. Plants and animals have changed through the ages.

Investigations

1. THE RESEMBLANCE OF LIVING THINGS TO THEIR PARENTS IS CALLED HEREDITY.

Background:



Equipment: ditto sheets (with an outline such as above), and pictures of the presidential family (optional).

A FAMILY TREE

Activity: Each child charts his own family tree, adding or deleting branches as necessary. Include such facts as: names, color of eyes, and other strong family resemblances.

If this activity is not suitable because of adopted children and orphans in the class, use the Presidential family. Perhaps a large "tree" complete with pictures could be constructed. Emphasize family resemblances.

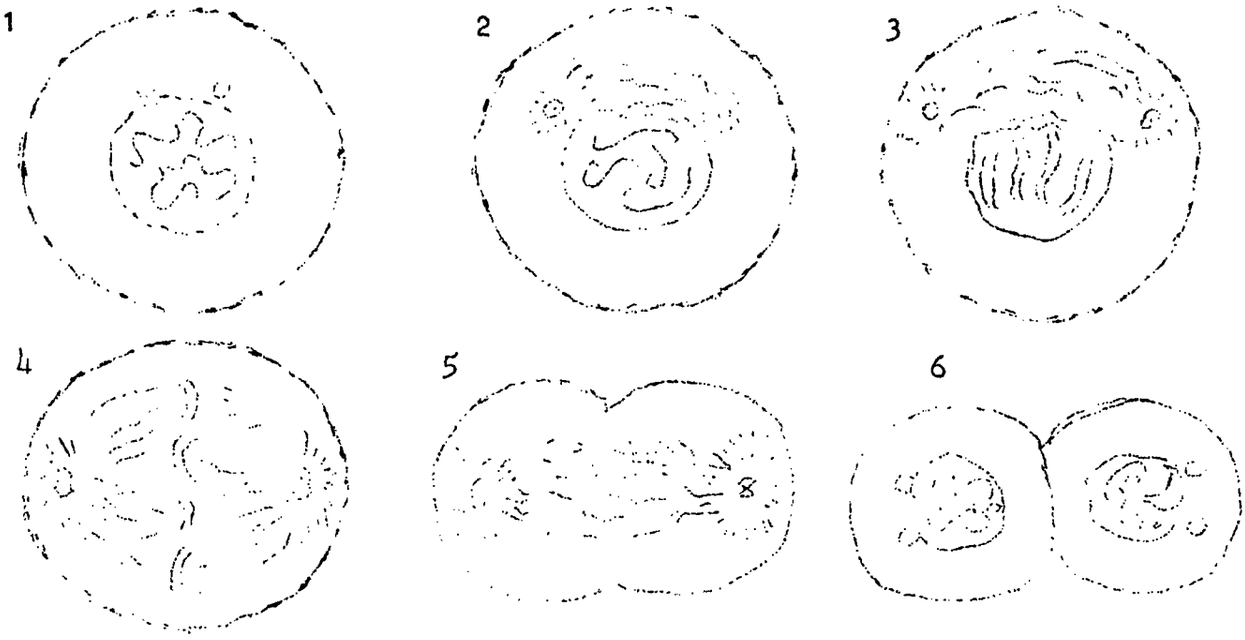
2. CHARACTERISTICS ARE PASSED ON THROUGH THE GENERATIONS BY CHROMOSOMES, WHICH ARE IN THE CELLS OF ALL LIVING THINGS.

Background: The nucleus is the control center of the cell. It is a round body that floats like a bubble in the cellular protoplasm. The nucleus contains a definite number of chromosomes. In man, the number is forty-six. Chromosomes always exist in pairs, and when cell division occurs one of each pair goes into one half of the cell. The chromosomes then snythesize from material in the nucleus, exact replicas of themselves. This process is called mitosis.

Meiosis is the division of the sex cells. In this case, after cell division the cell ends up with only one of each pair of chromosomes. When fertilization takes place and a sperm unites with an egg, the fertilized egg contains a full set.

Precise locations on the chromosomes that control specific characteristics are called genes. Often whole groups of genes are involved in producing a single trait.

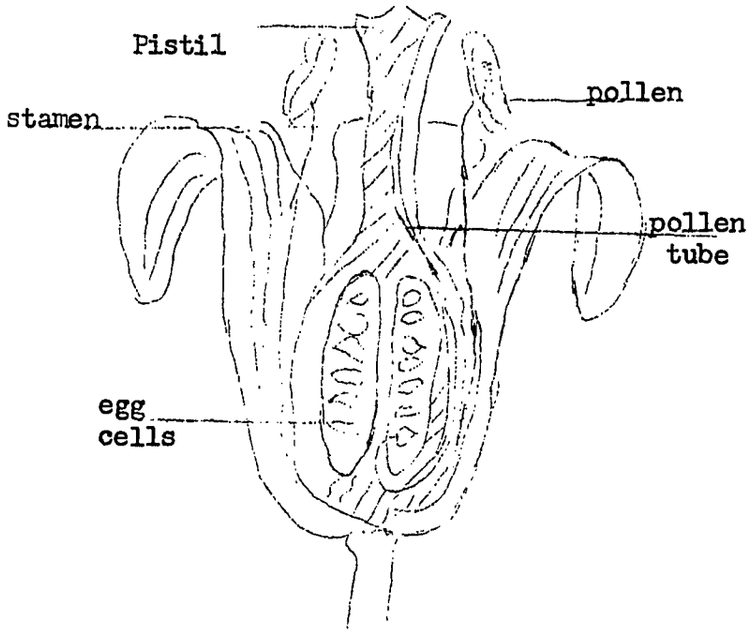
Chromosomes contain a large molecule called DNA (dioxyribonucleic acid). DNA is portrayed as a helix, a thin, ribbonlike molecule twisted around itself. This material in the chromosomes "tells" the organism how to develop.



A. Equipment: flowers (tulips are good), a sharp knife or razor.

DISSECTION OF A FLOWER

Activity: Cut apart the flower, identifying the stamens, pistil, and egg cells (seeds).

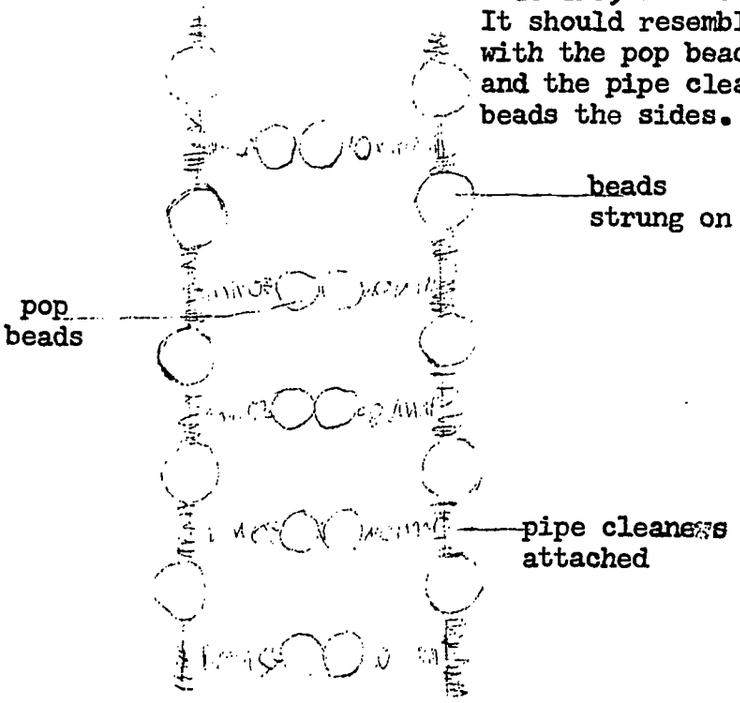


Extension: Prepare a bulletin board dealing with pollination.

B. Equipment: pipe cleaners (of various colors), pop beads, beads.

A MODEL OF DNA

Activity: Construct a model of a DNA molecule, as shown below. It should resemble a ladder, with the pop beads the rungs, and the pipe cleaners and beads the sides.



Finally, twist the "ladder" to complete the form of the DNA.

Extension: Find out about J.D. Watson, and F.H.C. Crick who won the Nobel Prize in 1962.

3. THE DEVELOPMENT OF A TRAIT IS CONTROLLED BY ENVIRONMENT.

Background: Surveys taken among Chinese-Americans have shown that the younger generations, raised in America are, on an average, taller then their fathers. In fact, men in the United States are becoming taller. This is interesting in light of the fact that tallness is recessive to shortness. This change is attributed to improved diet and medical care.

A. Equipment: a large white potato, flowerpots, soil

Activity: Investigate how invironment modifies the development of the inherited traits of a potato. It is better if the potato has already started to "sprout."

HEREDITY VS. ENVIRONMENT

Controlling factors:

1. All the "eyes" have identical heredity.
2. Cut the potato so that each bud has an equal piece of potato.
3. use the same type of soil for all the pots.

Variables:

1. amount of light
2. amount of water
3. temperature
4. food supply (cut down the amount of potato surrounding the bud)

You will need to set up a separated pot for each variable, plus a control. Measure everything!

In a week or so, it should be evident that a good environment is essential to the development of the potato buds.

B. Equipment: materials for taking a survey, paper, pencils, ditto master

A SURVEY

Activity: Take a survey of the heights of adult men and their fathers. First instruct the class to design a question sheet. Every student then interviews adults in his family and neighborhood. If specific measurements are difficult to obtain, approximate.

There are many ways of compiling the collected data.

4. THE STUDY OF HEREDITY IS CALLED GENETICS.

Background: Genetics is the science of heredity. It concerns itself with the growth and development of life, and ultimately with evolution.

The basic principles of heredity were formed by Gregor Johann Mendel, and Augustinian monk. Through carefully controlled experiments in the crossbreeding of peas he found he could control many of the plant's physical characteristics.

Plant and animal breeders use the science of genetics to develop new strains and maintain advantageous traits.

A. Equipment: seedless orange (navel), seeded orange (valencia), and/or seeded and seedless grapes.

GENETICS FOR PROFIT

Activity: Cut open the oranges and examine them. Discuss the advantages of seedless fruits (easier to eat,) more juice, greater profit for the raiser). If there are enough, compare the taste.

Extension: 1. Discuss the traits desired in milk cattle and beef cattle.

2. Find out about the experimental agricultural station at Beltsville, Maryland.

B. Equipment: reference books, and materials for reports and charts.

REPORTS AND CHARTS

Activities:

1. Direct the students in research on aspects of genetics that interest them. Some suggestions are:

a. Gregor Mendel
b. pedigreed animals
c. hybrids
d. Luther Burbank

2. Make charts illustrating:

a. varieties of roses (seed catalogs are a good source of pictures)

b. pedigreed dogs, cats, horses

5. A TRAIT THAT ALWAYS APPEARS IN THE OFF SPRING IF CARRIED IN THE GENES IS CALLED DOMINANT.

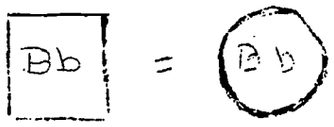
6. TRAITS THAT APPEAR ONLY WHEN DOMINANT GENES ARE NOT PRESENT ARE CALLED RECESSIVE.

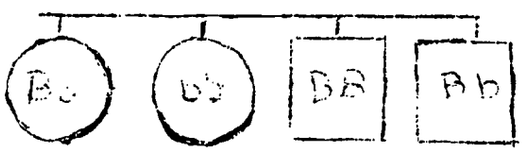
Background: The phenomenon of dominance supplies the explanation as to why an offspring may resemble one of its parents more than the other despite the fact that both make equal contributions to its genetic make-up.

A plant or animal with two genes exactly alike is called homozygous or "pure." An organism with one dominant and one recessive gene is said to be heterozygous or "hybrid." Probability ratios can be used to predict the appearance of a particular trait in offspring.

Eye Color in Man 3 : 1
(Brown eye color (B) being dominant to blue (b).

parents (heterozygous)





offspring

Some Traits in Man Known to be Inherited

Dominant	Recessive
dark hair	light hair
curly hair	straight hair
long eye lashes	short eye lashes
brown eyes	blue eyes
free ear lobes	attached ear lobes

shortness
taster of PTC

tallness
non-taster

A. Equipment: 100 blue beads, 100 brown beads, (any small objects will do), two bags

GENETIC RATIOS

Activity: Demonstrate the law of probability concerning the inheritance of eye color, when both parents are heterozygous. Put 50 of each color in the bags. Ask a child to choose a bead from each bag, randomly.

Record the combination and decide upon eye color. (Remember that brown is dominant.)

Put the beads back in the bags, and repeat the procedure 20-25 times. A ratio close to 3:1 should become apparent after compiling the data.

B. Equipment: PTC paper, (phenylthiocarbamide), available from:
American Genetic Association
1507 M Street N.W.
Washington, D.C. 20005

PTC TASTING

Activity: The ability to taste PTC is inherited. Distribute the papers, and let the children discover if they are PTC tasters. Record the results, and figure the percentages. (With large samples this is 70% tasters, 30% non-tasters).

Extension:

1. Make a study dealing with another trait such as ear lobes. Emphasize that using a large sample of people promotes accurate results.

2. Grow corn that demonstrates the 3:1 ratio. See appendix for where to write.

7. A MUTATION IS A NEW HEREDITARY CHARACTERISTIC RESULTING FROM A CHANGE IN THE GENES.

Background: A mutation results from a change in the genes, not from changing the characteristic. Generations of spaniels have had their tails bobbed, yet the offspring have long tails. The Manx cat, on the other hand, owes its stubby tail to a mutation in some ancestor.

Mutations occur constantly, randomly. Six-toed (double paw) cats are a mutation that most of the children will be acquainted with. Mutations can be produced artificially by x-rays and chemicals. Most mutations are not conducive to the survival of the organism, and they soon die.

Equipment: pots, soil, irradiated seeds (see teaching aids), regular seeds

GROWING MUTATED PLANTS

Activity: Plant and grow some irradiated and regular seeds. Observe them carefully and note any changes, and differences.

Extension: Investigate and prepare reports on:

1. Ancon sheep
2. polled cattle
3. Dr. Hermann Muller

8. PLANTS AND ANIMALS HAVE CHAGED THROUGH THE AGES.

Background: The role of mutations as the raw material for natural selection and evolution is now universally recognized. Most mutations are harmful, but some mutations may be of adaptive value. These mutations may make the organism better fitted to survive in the environment and give rise to offspring that are also well adapted to their environment.

A simple and less spectacular way than mutation by which species change is hybridization. The best characteristics of each organism may be combined in the offspring, making it better able to survive than either of its parents.

Scientists have studied the ancestors of the modern horse and have traced the changes in form. Eohippus had three hind toes and was about a foot tall. Mesohippus ran mainly on its center toe, and was about two feet tall. Pliohippus had one toe and was about five feet high. Eqisus is today's horse.

Equipment: reference books, such as those listed in the bibliography

REPORTS AND CHARTS

Activity: Direct the students in research dealing with the ancestors of present day animals such as tiger, and the science of paleontology. The results may take the form of reports or charts.

Extension: 1. Find out why dinosaurs became extinct.

2. Make a chart of the eras of prehistoric time.

3. Do research on the LaBrea tar pits in Los Angeles.

APPENDIX

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Greene, Carla. After the Dinosaurs. Bobbs, 1968.

Karp, Walter and Dr. J. W. Burrow. Charles Darwin and the Origin of the Species. Amer. Heritage, 1968.

Randal, Judith. All About Heredity. Random House, 1963.

Selsam, Millicent E. Around the World With Darwin. Harper and Row, 1960.

Zim, Herbert S. What's Inside of Plants? Morrow, 1952.

Text References

Barnard, Jr. Darrell, et al. Science for Tomorrow's World 6. MacMillan, 1966. pps. 329-333.

Brandwein, Paul F., et al. Concepts in Science 6. Harcourt, Brace and World, 1966. Unit 8.

Teaching Aids

Booklets

"Story of Plants." - Free

"Story of Meat Animals" - Free

Agricultural Research Dept.
Swift and Co.
Union Stock Yards
Chicago 9, Illinois

Chart

"Combat With a Traitor - Cancer" (cell reproduction) - Free

(address on following page)

Other Materials

PTC Paper

American Genetic Assoc.
1507 M Street, N.W.
Washington, D.C. 20005

Seeds for Genetic Studies

L. G. 700 Corn $2.50
green/albino 3:1 ratio

Connecticut Valley Biological
Supply Co., Inc.
Valley Road
Southhampton, Mass. 01073
Tel. 1-413-527-4030

Irradiated Seeds

Carolina Biological Supply
Burlington, N. Carolina

Filmstrips

"Animals of Long Ago." 3 - 1 A3
Parts of a Flowering Plant 3 - 1 B3
"Man Improves Plants and Animals" McGraw-Hill
"Heredity" McGraw-Hill

ROTATION, REVOLUTION, AND TIME

Overview

Rotation, Revolution, and Time is a unit in the field of astronomy dealing with motion in the universe. Through this unit the students will learn that the universe is in constant change, but that there is an orderliness in this change that enables them to predict.

It is assumed that the students have been exposed to some aspects of astronomy in previous grades. Therefore, an attempt has been made to pursue the subject of motion in greater depth, with emphasis on the ways in which scientists have accumulated this knowledge. The students will observe and record the movements of the sun, moon, and stars and make models to study these phenomena. They will make and use simple sextants and telescopes, and learn to compute speed and measure mass. They will observe the phenomenon of parallax and learn to analyze through the technique of sampling. Keeping both feet on the ground, they will travel through the universe.

CONCEPTS TO BE DEVELOPED

1. The earth's rotation causes the apparent motion of the sun, moon, and stars across the sky.

2. The sun is the center of our solar system, around which the planets (with their moons), the asteroids, meteors, and comets orbit.

3. A stable orbit is achieved if there is a balance between the forward velocity of a body and the rate at which it is pulled by gravity.

4. Velocity can be measured.

5. The planets do not remain in the same direction from the earth, but their relative positions change in a predictable pattern.

6. The seasons are caused by the tilt in the earth's axis and the revolution of the earth around the sun.

7. The apparent changing shape of the moon is the result of the movements of the moon and the earth in such a way that varying degrees of the moon's reflectiong surface can be seen from the earth.

8. Because the earth is constantly moving around the sun, a different part of the sky can be seen at the same hour each night of the year.

9. Nuclear reactions are the source of the sun's energy.

10. The apparent brightness of a star depends on its distance from the earth, its size, and its temperature.

11. Scientists estimate the number of stars using sampling.

12. Parallax can be used to measure the distances from earth to the planets and some of the stars.

13. Our galaxy, the Milky Ways, is revolving around its center, like a giant wheel.

14. The universe is in constant motion.

MOTIVATING IDEAS

1. Prepare a do-you-know-why bulletin board. Include pictures of planets, the moon in various phases, pictures characteristic of the seasons, other galaxies, etc.

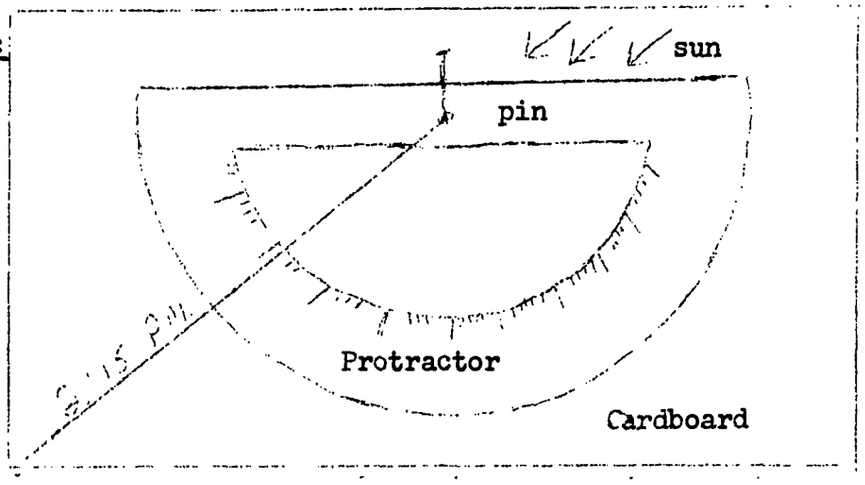
2. Discuss the conceptions held by people long ago regarding the shape of the earth and the nature of the universe.

Investigations

1. THE EARTH'S ROTATION CAUSES THE APPARENT MOTION OF THE SUN, MOON, AND STARS ACROSS THE SKY.

Note: Some groups of children may be more familiar with this concept than others. Choose activities that you feel will be best suited for your class.

Background:



Equipment: protractors, pins, cardboard, rulers, pencils.

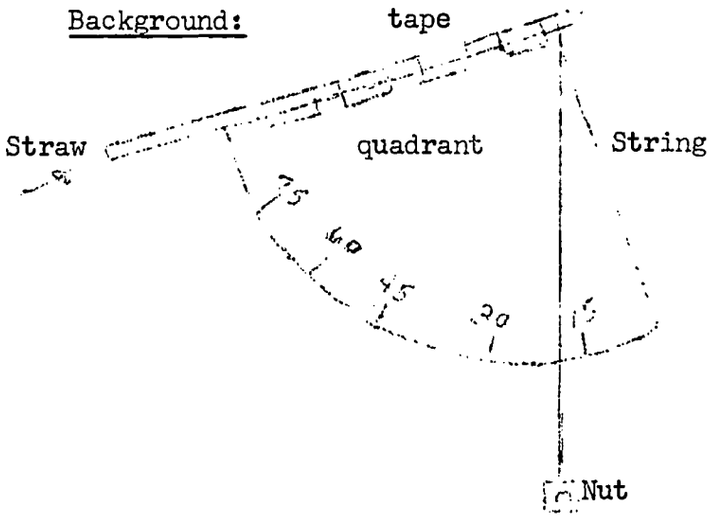
SHADOW CLOCKS

Activity: Place the "shadow clocks" in the sun light. Using a ruler and pencil, record on the cardboard where the shadow from the pin falls, and mark the time. Repeat this at regular intervals.

Most classrooms receive sunlight during at least part of the day. These shadow clocks are only 'part day' clocks since the shadow is visible only part of the school day.

Extension: Tomorrow use the shadow clocks to tell what time to go to recess, (lunch, dismissal).

Background:



B. Equipment: protractors, string, a small weight, (a nut or bolt is good), straw

MAKING A SEXTANT

Activity: Observe the Big Dipper (Ursa Major) just after it gets dark. With the sextant, determine the angle of Dubhe above the horizon, Later, just before bed, repeat the process. Record your results.

Extension: 1. With the sextant, determine the angle to the North Star (Polaris) from where you live.

2. Use a camera to "track" the stars. The camera must have a time exposure setting. Point the lens toward Polaris and leave the shutter open for an hour.

2. THE SUN IS THE CENTER OF OUR SOLAR SYSTEM, AROUND WHICH THE PLANETS (WITH THEIR MOONS), THE ASTEROIDS, METEORS AND COMETS ORBIT.

Note: This major concept is developed through a series of developmental activities. The content and order of the activities are left to the discrimination of the teacher.

Background: The mass of an object causes the gravitational pull between it and the mass of some other object. The tremendous mass of the sun compared to that of the other members of the sun's family causes it to be the body most strongly influencing the gravitational field of the solar system.

Equipment: spring balances, pan balances, scales, weights (pins, pennies, pencils).

MEASURING MASS

Activity: Practice measuring the weight of objects, using pounds and ounces, grams and kilograms. Using the scales, find the weight of each pupil. Then compute the weight of the child on the moon and Jupiter. Stress that their mass would stay the same.

Extension:

1. Which body in the solar system has the most mass? Which has the greatest gravitational pull? Discuss the implications.
2. Find out about the various concepts man has held through the ages of the earth, sun, and stars.
3. Make a chart listing facts about the sun.

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THE NINE KNOWN PLANETS	MEAN DISTANCE FROM SUN Millions of Miles	DISTANCE TO SCALE	MEAN DISTANCE FROM SUN Millions of Kilometers	DIAMETER MILES
Mercury	36	1 3/4"	58	3,100
Venus	67	3 1/4"	110	7,600
Earth	93	4 1/2"	150	7,900
Mars	142	7"	230	4,200
Jupiter	483	2 ft.	780	88,000
Saturn	886	3'8"	1,400	75,000
Uranus	1,783	7'5"	2,900	29,000
Neptune	2,794	11'8"	4,500	28,000
Pluto	3,670	15'3"	5,900	3,600

SUBCONCEPT:

THE PLANETS VARY IN SIZE, RATE OF MOVEMENT, AND MEAN DISTANCE FROM THE SUN.

Background:

Chart above.

DIAMETER TO SCALE	DIAMETER KILOMET-ERS	TIME OF ROTATION	TIME OF RE-VOLUT-ION	MOONS	TEMP. FAREN-HEIT	FOOT-BALL FIELD
1/4"	5,000	58 days	88 days	0	700°	1 yd.
5/8"	12,000		225 days	0	585°	2 yd.
5/8"	13,000	24 hours	365¼ days	1		3 yd.
3/8"	6,800	24 hours	688 days	2		4 yd.
6 3/4"	140,000	9.9 hours	12 yrs.	12	-200°	14 yd.
5 1/2"	120,000	10 hours	29 yrs.	9	-240°	25 yd.
2 1/4"	48,000	10.7 hours	84 yrs.	5	-300°	50 yd.
2 1/4"	45,000	15.7 hours	165 yrs.	2	-300°	80 yd.
3/8"	6,800	16 hours	248 yrs.	0	-300°	105 yd.

MOTION OF THE SOLAR SYSTEM

Optional Activities: 1. On large paper draw the Solar System to scale.

2. Make a mobile of the planets in order.

3. Prepare a bulletin board about the Solar System.

4. Pace out the Solar System to scale on a football field.

Extension: 1. Search for information about asteroids.

2. Construct a chart showing the orbit of Halley's Comet, or Encke's Comet.

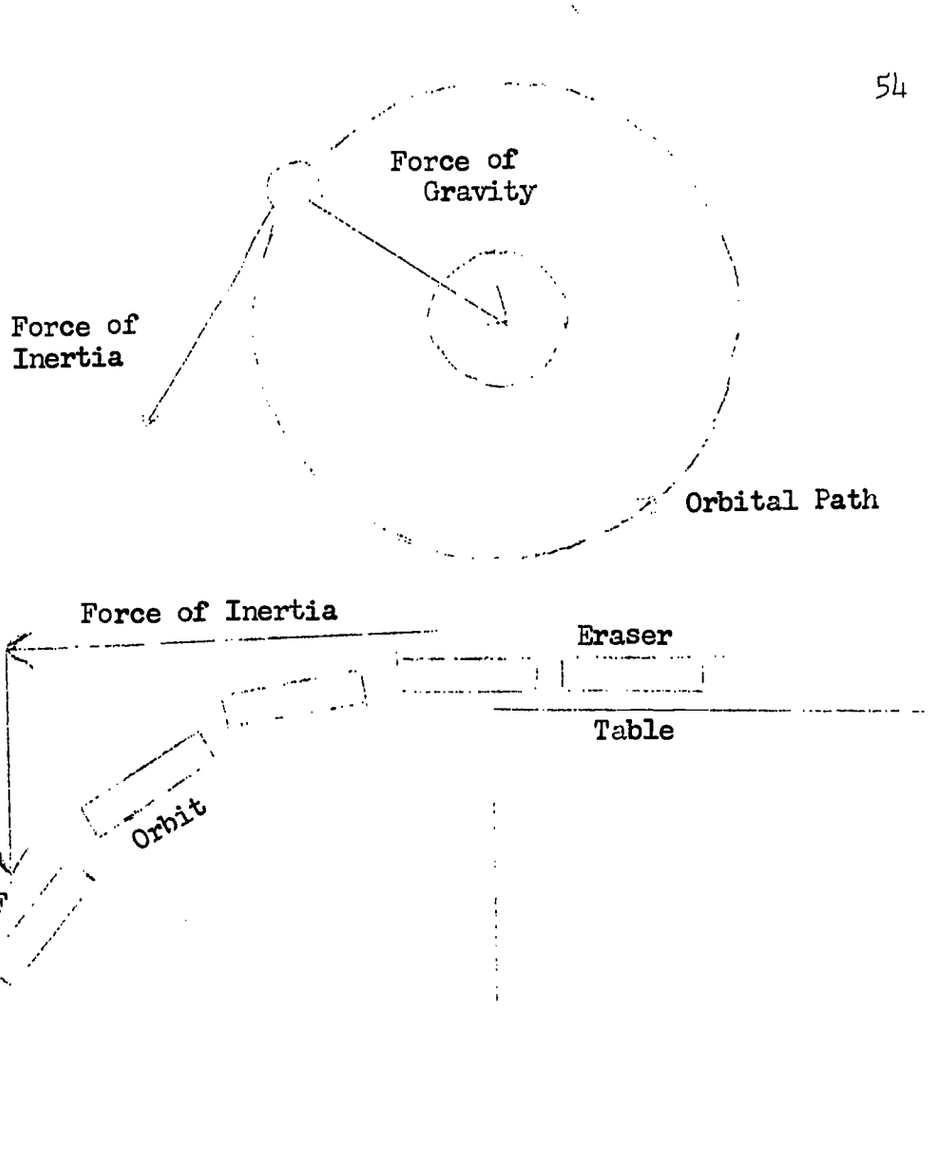
3. Find out about the Chubb Crater in Quebec.

3. A STABLE ORBIT IS ACHIEVED IF THERE IS A BALANCE BETWEEN THE FORWARD VELOCITY OF A BODY AND THE RATE AT WHICH IT IS PULLED BY GRAVITY.

Background: According to Newton's first law of motion, a body once set in motion tends to maintain that motion in a straight line, unless disturbed by some other force. The effect of gravity, however, is to pull the body toward a larger mass. The resultant orbit is maintained as long as no other outside force influences this balance.

In an elliptical orbit, the point at which the satellite comes closest to the earth is called the perigee, the point of greatest distance the apogee. At apogee the satellite reaches minimum velocity and begins to fall earthward, gaining velocity until its maximum speed is reached at perigee. Here sufficient velocity is reached to overcome gravity and it begins to move upward into space, gradually losing momentum as apogee is approached.

See diagram on the following page



"ORBITING" AN ERASER

Equipment: blackboard eraser, chalk, string, spool, a light weight (gum eraser, nut), an object two or three times as heavy.

Activity: A. Push the eraser off the edge of a desk at different speeds. Mark where it hits the floor each time. Help the pupils generalize that the faster the eraser is traveling, the further it will travel through the air before striking the floor.

B. Thread a two foot length of string through a spool. To one end fasten the light weight, to the other end, tie the heavy weight. Move the spool so that the lightweight travels in a circle overhead. Observe that when the smaller weight is traveling with enough speed, the centrifugal force developed is sufficient to lift the heavier object..

Extension: 1. Speculate upon the effects which would be experienced if gravitational force did not exist.

2. Find out about the contribution of Isaac Newton to science.

4. VELOCITY CAN BE MEASURED

Background: $\text{Velocity} = \frac{\text{distance}}{\text{time}}$

Equipment: yardsticks and/or metersticks, clock or watch with second hand, stop watch (optional), softball.

Activity: The students measure the velocity with which they can throw a ball. A large area is needed.

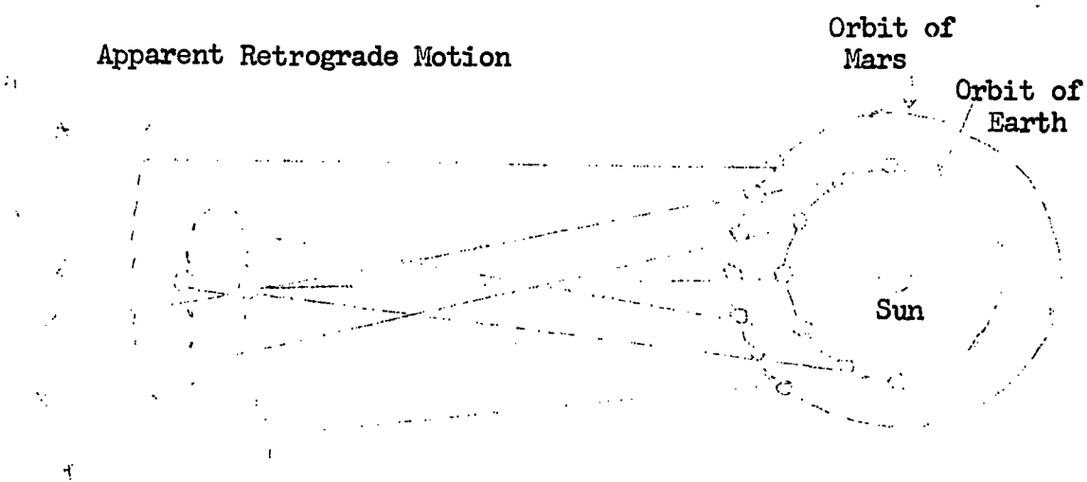
Extension: 1. Measure the velocity in miles per hour of the rotation of the earth. The earth is about 25,000 miles in circumference.

$$V = \frac{25{,}000}{24 \text{ hrs.}}$$

2. Measure the velocity in meters per second, for the 50 meter dash.

5. THE PLANETS DO NOT REMAIN IN THE SAME DIRECTION FROM THE EARTH, BUT THEIR RELATIVE POSITIONS CHANGE IN A PREDICTABLE PATTERN.

Background: The planets travel at different speeds. Thus, they do not stay at constant distances from the earth. This is what causes their apparent "retrograde" motion. The periods of revolution of the planets are related to their distances from the sun.



Equipment: record player, chalk, name tages (Earth, Mars, Venus, Mercury, Sun).

RETROGRADE MOTION

Activity: Seeing is not always believing. Have the children observe the object revolving on the record player. Then elevate the record player to eye level. The object appears to move back and forth!

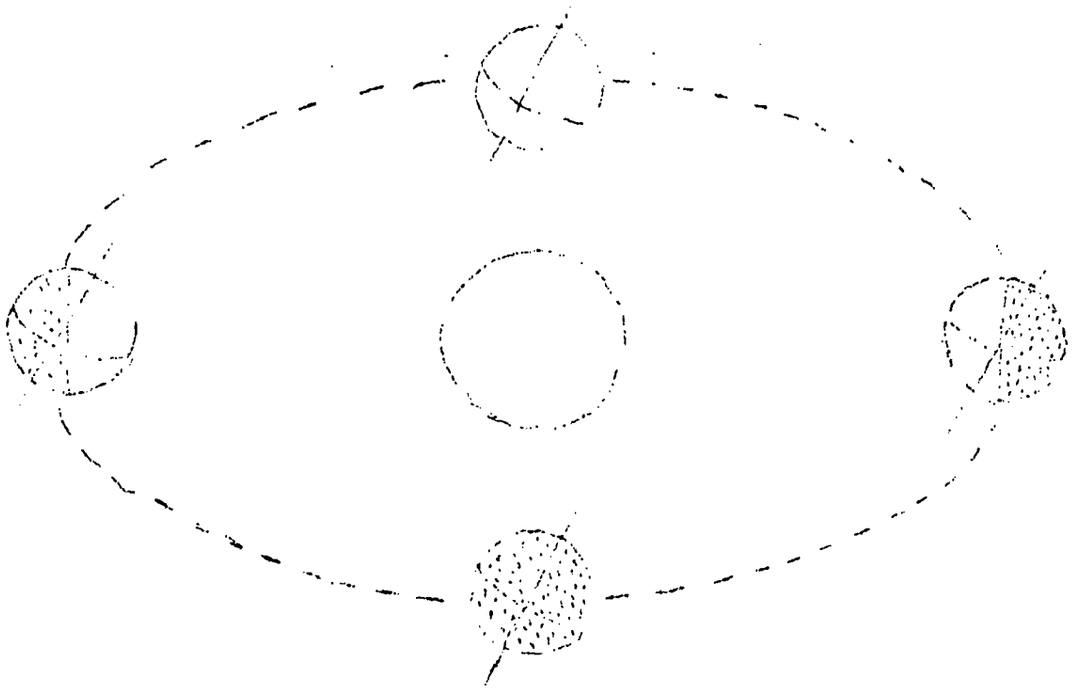
Discuss the apparent "backward" motion of an automobile that is being passed on a highway. Actually both are going forward!

Make four concentric chalk circle on the floor. (you may want to go outside or use a large area.) Choose pupils to be the Earth, Mars, Venus, Mercury and the Sun. Another child is timekeeper. Position the Sun, Earth and Mars in their orbits. When the timekeeper claps his hands Mars takes one step, the Earth takes two. Do this several times, comparing the positions of the Earth and Mars. Have Earth report on whether he has to look forward, across, or behind to see Mars. Complete one revolution of Mars. Now add Venus - three steps per clap; Mercury - four steps per clap. Compare.

Extension: Do research on the Ptolemaic model of the Solar System.

6. THE SEASONS ARE CAUSED BY THE TILT IN THE EARTH'S AXIS AND THE REVOLUTION OF THE EARTH AROUND THE SUN.

A. Background:



Equipment: A strong source of light (a bare light bulb) a globe.

THE SEASONS

Activity: Darken the room, and turn on the light mentioned above. Keeping the axis tilted at $23\frac{1}{2}^{o}$, make one revolution of the light. Emphasize the fact that at some times of the year the poles are in 24 hour darkness. Discuss the relation of the angle of the sun's rays to the seasons.

Extension: 1. Consult an almanac to determine the time of sunrise and sunset at various dates during the year. Chart the information.

2. Find out about ancient calendars.

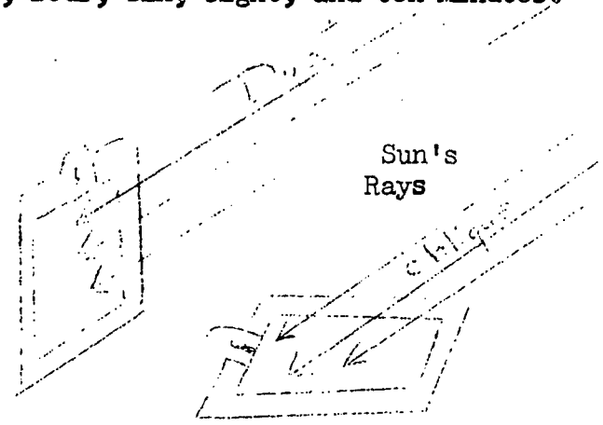
3. Find out about leap year.

B. Background: When the sun is overhead, it heats the earth more than it does when it is lower in the sky and its rays strike the earth more obliquely.

Equipment: two pieces of black paper, two pieces of corrugated cardboard, two thermometers, pins.

THE SUN'S RAYS

Activity: Place the pieces of black paper on the pieces of cardboard with pins. Slip thermometers between the paper and cardboard. Place one to receive the sun's direct rays, another on a flat surface. Compare warmth after two, four, six, eight, and ten minutes.



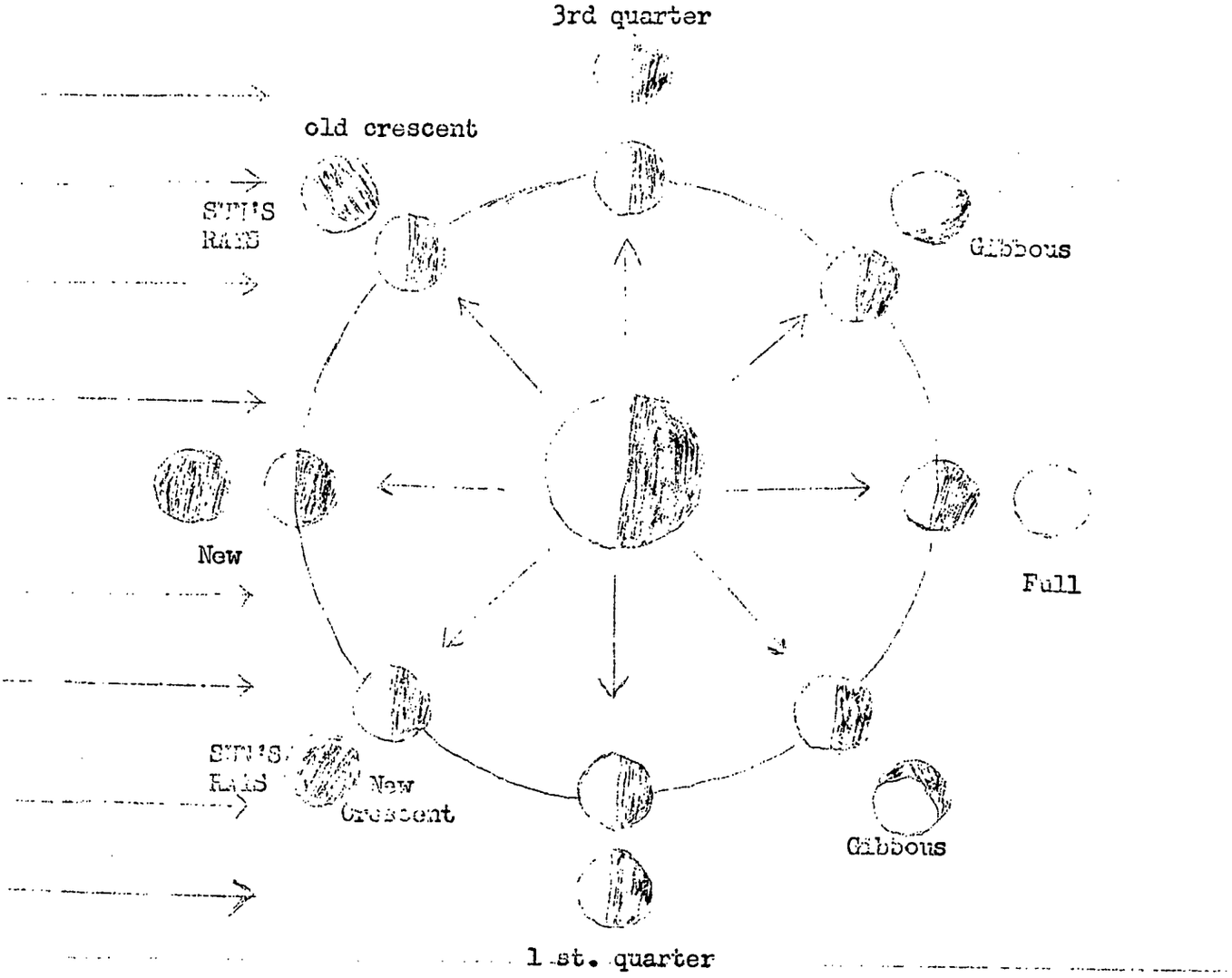
Extension: 1. Compare the seasons of the Northern Hemisphere and the Southern.

2. What is an equinox?

7. THE APPARENT CHANGING SHAPE OF THE MOON IS THE RESULT OF THE MOVEMENTS OF THE MOON AND THE EARTH IN SUCH A WAY THAT VARYING DEGREES OF THE MOON'S REFLECTING SURFACE CAN BE SEEN FROM THE EARTH.

Background:

PHASES OF THE MOON



PHASES OF THE MOON

A. Equipment: a strong source of light, ball, string, yardstick

Activity: Darken the room. Use the light to represent the light from the sun. Tie the ball on a string and suspend it from the end of the yardstick. Ask a child to be the "earth" and tell the class how much of the lighted portion of the ball he observes. The class is in "outer space," and continually sees half of the ball lighted as it rotates the earth. Have several children be the earth and observe the moon's phases

Extension: 1. Discuss why the phases of the moon are seen from the earth's surface but would not be observed from another planet.

2. Make charts that explain solar and lunar eclipses.

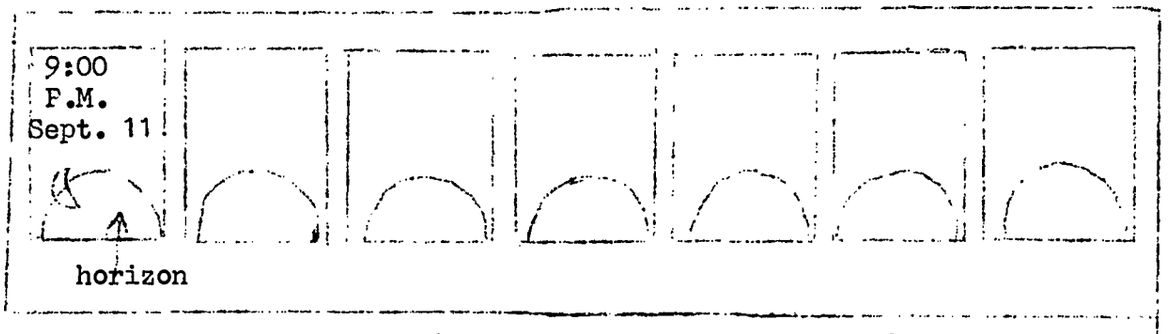
3. Find an explanation for the "man in the moon."

OBSERVING THE MOON

B. Equipment: protractors, string, and a small weight, compasses (see activity 1-B)

Activity: Observe the moon at the same time for four nights in a row. With the sextant, determine the angle of the moon above the horizon. With the compass find the direction of the moon. Make sketches of the moon each night. Compare your results.

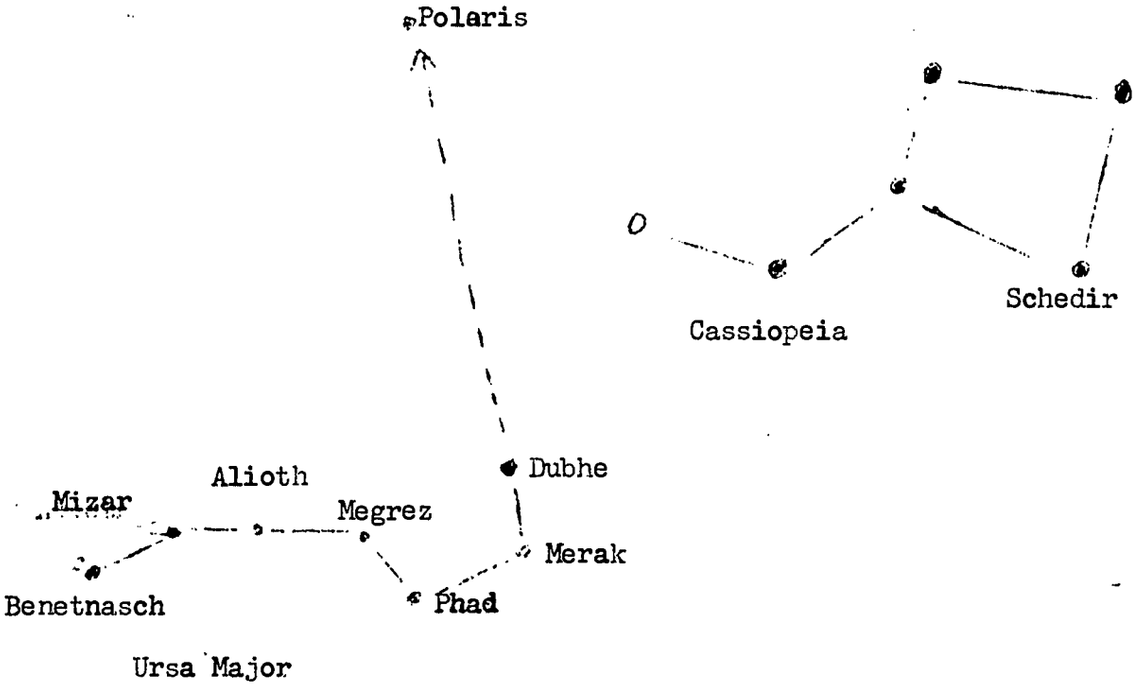
Extension: 1. Make a moon calendar. Draw the shape of the moon each day. Also, show where it is in the sky, and note the time.



2. Gather information about why the moon appears larger as it rises above the horizon than when it is high in the sky.

8. BECAUSE THE EARTH IS CONSTANTLY MOVING AROUND THE SUN, A DIFFERENT PART OF THE SKY CAN BE SEEN AT THE SAME HOUR EACH NIGHT OF THE YEAR.

Background:



Equipment: a globe, a source of light

THE
CONSTELLATIONS

Activity: Darken the room. Use the light to represent the sun. Have the students locate the place where they live on the globe. Then they observe the part of the room that is visible from their location when the globe is turned toward the lamp and away from the lamp at each of the seasons. This should enable the pupils to understand why certain constellations are visible in winter, while others appear in summer. The winter constellations do not dissappear, but rather are present during the day in summer.

Extension: A constellation chart can be used as a star locator out-of-doors, and/or an activity sheet.

9. NUCLEAR REACTIONS ARE THE SOURCE OF THE SUN'S ENERGY.

Background: In nuclear reactions, the nuclei of atoms are divided (fission) or combined (fusion).

MAKING A MODEL OF THE ATOM

Activity: Make a three dimensional model with clay and wire, of an atom.

Extension: 1. Find out about Albert Einstein.

2. Make a model of a nuclear reactor.

10. THE APPARENT BRIGHTNESS OF A STAR DEPENDS UPON ITS DISTANCE FROM THE EARTH, ITS SIZE, AND ITS TEMPERATURE.

Background: Scientists cannot yet travel to the stars and examine them, they have to devise ingenious systems of measurement, and observe the sky carefully from earth.

The color of a star is an indication of the surface temperature. The hottest stars are blue--white. Cooler stars are yellor, and the coolest are red. There are red. There are "dark" stars which give no light at all. Our sun is yellow, and a medium sized star.

Color is also an indication of a star's size. There are "red giants," such as Betelgeuse, and "white dwarfs" such as Vega. However, a red star like Betelgeuse (5,500°F), gives off more heat than Vega (22,000°F), because of Betelgeuse's greater mass.

A. Equipment: electric hot plate, four beakers, ice cubes, water, a thermometer.

HEAT AND TEMPERATURE

Activity: Plug the hot plate and observe the colors of the heating element. The students should infer that brighter color indicates a high temperature. Boil some water in one of the beakers, fill another with tap water. Record the temperatures. Put four ice cubes in the two remaining beakers. Pour one inch of boiling water into one of the beakers containing ice cubes. Put the flask of tap water into the other. Record the melting time. Discuss the fact that the tap water had more heat, even though the temperature was lower, because of its greater mass.

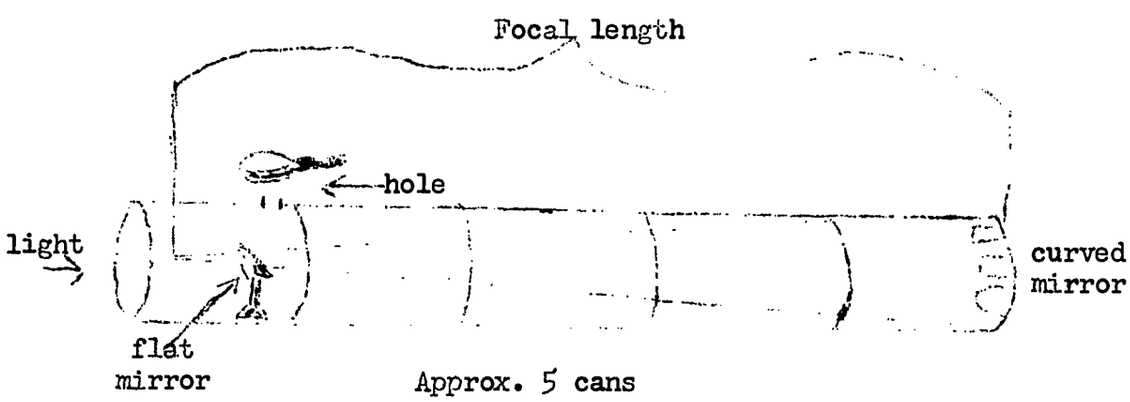
Extension: 1. Find out about the explosion of stars called Supernovas.

2. Find out about a spectroscope, an instrument that analyzes light.

B. Equipment: a curved mirror (magnifying side of a shaving mirror), a flat mirror, 1" x 1", several round cardboard or metal containers, masking tape, wire (coat hangers), scissors or tin shears, yardstick, pliers, plasticene, magnifying glass.

A SIMPLE TELESCOPE

Activity: Hold the curved mirror so that it reflects light from a window onto a sheet of paper. Adjust the distance between the mirror and the paper until the sharpest possible image is formed. Measure this distance. Remove the ends from the round containers and join them with tape. The telescope tube should be as long or longer than the focal length measured above. Mark the focal length on the outside of the tube. Tape the shaving mirror to the open end. Measure the radius of the tube and add one more inch. Mark this on the outside of the tube, starting from the focal length and going backwards. Cut a hole one inch square around this mark. Support the flat mirror, using wire and plasticene, in the tube under the hole. Adjust it until you can clearly see the curved mirror when looking down through the hole. Use a magnifying glass to enlarge the image.



Approx. 5 cans

11. SCIENTISTS ESTIMATE THE NUMBER OF STARS USING SAMPLING.

Background: The Milky Way Galaxy has approximately 100,000,000,000 stars.

Equipment: jar or fish bowl, three boxes of different colored beans, toothpicks, rulers

Activity: Introduce the jar full of beans. Have the students devise ways of estimating the amount. Discuss their plans and then introduce the idea of sampling. Take a sample of the beans, and analyze it as to number and color. When the jar is half full, estimate the total number.

Now try the same investigation with toothpicks spread on a table. Use a square foot area as a sample.
Discuss how the results of the activity can be applied to counting large numbers of stars.

Extension: 1. Make a plan to estimate the number of worms in a garden.

2. Find out about our galaxy, the Milky Way.

12. PARALLAX CAN BE USED TO MEASURE THE DISTANCES FROM RARTH TO THE PLANETS AND SOME OF THE STARS.

Background: Parallax is the apparent movement of an object against its background, when the object is seen from different locations. The position of the earth at different times in its orbit can be used to establish a base line. Even the distance between the eyes can cause parallax.

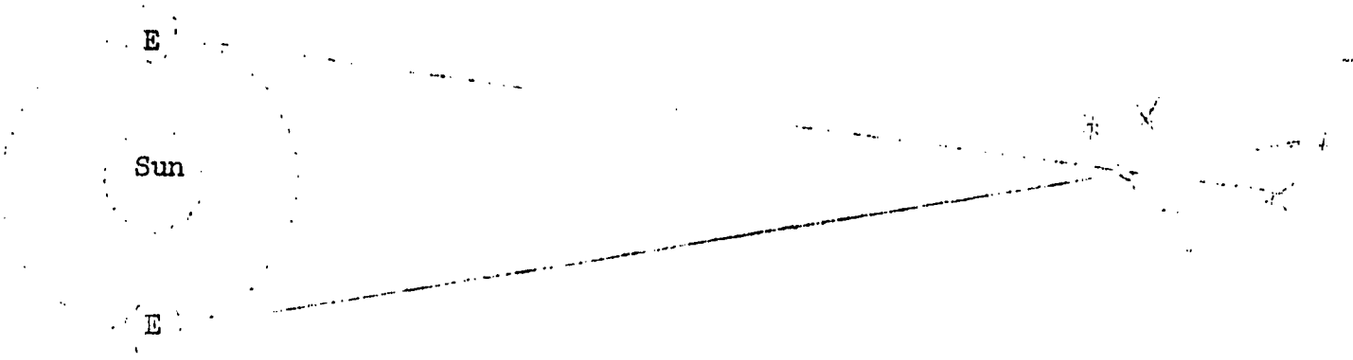
Equipment: pin, cork, two rulers

Activity: Place the rulers in a "T" formation. The top of the "T" is propped up so that it stands on edge. Put the pin in the center of the cork, and place it at various positions along the stem of the "T" set up. With the chin resting at the bottom of the "T", record readings with the left eye, then the right. Emphasize that parallax is used by scientists to determine the nearness of stars.

Extension: 1. Find out about a light year.

2. Draw a diagram showing how scientists measured the distance to Alpha Centauri, 4.3 light years of (26 trillion miles away) using the revolution of the earth as a base line, and other stars as reference points.

See following page for diagram



13. OUR GALAXY, THE MILKY WAY, IS REVOLVING AROUND ITS CENTER, LIKE A GIANT WHEEL.

Background: Our galaxy is a huge system of stars, gas, and dust. It is a spiral galaxy that takes approximately 200 million years to complete a rotation. Much is still not know about the motion of the galaxy. Most of what has been complied has been learned by studying other galaxies, such as Andromeda, which are similar to the Milky Way galaxy.

Equipment: phonograph, heavy paper, pencil

MAKING A SPIRAL

Activity: Attach the paper to the turntable as you would a record. Turn on the phonograph to the fastest speed. Place the pencil near the center and draw a straight line toward the edge. The resulting design should be a spiral.

Extension: 1. Draw a diagram of our galaxy on graph paper. Use a scale of ¼ inch=1000 light years.

2. Find out about another spiral galaxy such as Andromeda, which can be seen in the northern hemisphere as a faint glow in the Andromeda constellation.

14. THE UNIVERSE IS IN CONSTANT MOTION.

Background: There are various theories of the universe, none of which definitively explains its origin. According to one suggestion, (evolutionary theory) the universe started as a large explosion. According to a different theory, (steady state theory) the universe has always been very much the same, with new galaxies forming, as older galaxies move farther apart. Neither of these accounts for the origin of the mater and energy that make up the universe.

However, scientists do concur that the universe seems to be expanding and changing. Nothing in the universe remains the same as it was a moment ago.

Equipment: balloon, magic marker

A MODEL OF EXPANSION

Activity: Partially blow up the balloon. With the marker, draw a number of dots to represent galaxies. As you blow up the balloon, observe the motion of the "galaxies." Have the students imagine how the movement of the galaxies would appear if they were living in one of the dots. (Which they are.)

Extension: 1. Find out more about scientists' theories of the origin of the universe. Key names- Fred Hoyle and George LeMaitre.

2. Write a complete address, including planet, system, galasy, and universe.

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FILMSTRIPS

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The Solar System and Space Travel
(transparency-duplicating book)

Sky Publishing Corp.
Harvard College Observatory
Cambridge, Mass. 01922

Send for price list of charts and photographs.

Prices as of Fall 1969

Light

Overview

This unit covers basic information on light, its nature and behavior. Background material presented with certain concepts should be discussed with students before performing the activities. Care should be taken that they thoroughly understand words and terms underlined throughout the unit. The concepts should be discussed in order, although activities may be chosen or deleted at will. Depending on the ability of the class the teacher may wish to terminate the unit at Concept #10 or devote more time to Extension Activities.

CONCEPTS TO BE DEVELOPED

1. Light is a form of energy that is transferred from other forms of energy.

2. Light acts in some ways like waves and in other ways like a stream of particles.

3. Scientists now believe that light is composed of packets of energy called photons which travel in waves.

4. Light usually travels in straight lines.

5. Different materials obstruct light beams in varying degrees.

   a. Transparent materials allow light rays to pass through them undisturbed.

   b. Translucent materials diffuse light beams as they pass through them.

   c. Opaque materials do not allow light rays to pass through them.

6. Light may be reflected from surfaces with or without being scattered.

7. Light may be absorbed by various materials and converted to heat energy.

8. Shadows are produced when light shines on opaque objects.

9. Light is refracted when it passes through certain materials.

10. Light waves have amplitude, frequency, and speed.

11. Light waves travel at the speed of 186,000 miles per second through space.

12. Sunlight may be broken up into an orderly sequence of colors called the spectrum.

13. The color of light is determined by the frequency of its waves.

14. Visible light is only a small part of the electromagnetic spectrum.

APPROACH TO INTRODUCING THE UNIT

Light is so very natural in daily living today that one usually gives little thought to it or its effects on man. A real awareness of its presence can produce an interest in and curiosity about its nature and behavior.

Suggested Activities:

1. Darken the class room for a few minutes. Notice objects still visible and those now invisible. Describe any physical or emotional changes that seem to occur in you when in darkness.

2. Light a candle in the center of a small room that is completely dark, Note and describe all effects.

3. Read The Night The Lights Went Out, published by the New York Times, for an excellent account of people suddenly forced to live in darkness. The book describes the New York power failure of 1965.

Investigations

1. LIGHT IS A FORM OF ENERGY THAT IS TRANSFERRED FROM OTHER FORMS OF ENERGY.

A.

A. Equipment: needle, tweezers (to hold the needle), candle

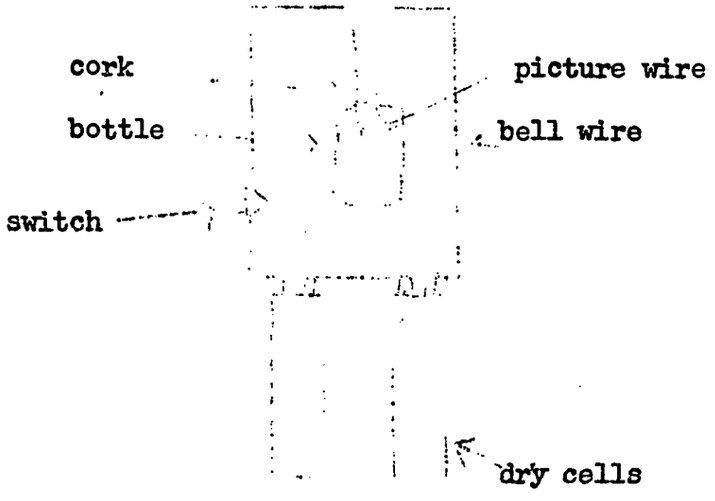
Activity: Hold the needle in the candle flame and observe the changes occurring as the needle becomes hotter. Heat energy is being transferred to light energy.

B. Equipment: friction (electrician's) tape, a dark room

Acticity: Pull the tape with a quick motion. The faint glow produced shows mechanical energy changing to light energy.

C. Equipment: switch, bottle, two pieces of bell wire, each 12" picture wire, flat cork, two dry cells

Activity: Scrape the insulation off the ends of the wire. Thrust one end of each wire into a flat cork. Wind some picture wire around the projecting ends of the bell wire. Fit the cork into a bottle, with the picture-wire loop inside the bottle.
You now have a model of an electric light bulb. Connect the bulb to two dry cells and put a switch in the circuit. Close the switch and observe the picture wire filament. Electrical energy is being changed into light energy.
Why does the filament eventually burn away?



D. Activity: Find information on the firefly and angler fish, showing how they produce light from chemical energy.

2. LIGHT ACTS IN SOME WAYS LIKE WAVES AND IN OTHER WAYS LIKE A STREAM OF PARTICLES.

3. SCIENTISTS NOW BELIEVE THAT LIGHT IS COMPOSED OF PACKETS OF ENERGY CALLED PHOTONS WHICH TRAVEL IN WAVES.

Background: About 300 years ago Sir Isaac Newton, a British scientist, suggested that light travels in particles (called corpuscles). Slightly earlier a Dutch scientist, Christian Huygens, suggested that light travels in waves. These two theories are now combined into the photon theory which says that bundles of light energy move along in separate little packets called photons. It is the photons that spread out in waves.

A. Equipment: two filmstrip projectors, each with a film in place, two large white papers to be used as screens

Activity: Darken the room. Turn on one of the projectors to shine a picture on white paper and examine the picture. Turn off the first projector and repeat the activity with the second projector. Then turn on both projectors so the light beams pass through each other. Examine the pictures on each screen and notice they have not changed.
If light consisted of tiny particles some of them would have collided as the beams crossed and scattered, thus spoiling the picture. Since waves pass through each other when they collide, this experiment demonstrates light behaving like waves.

B. Activity: Find information on light meters and the photoelectric effect they produce. This effect is best explained by the particle theory of light.

4. LIGHT USUALLY TRAVELS IN STRAIGHT LINES.

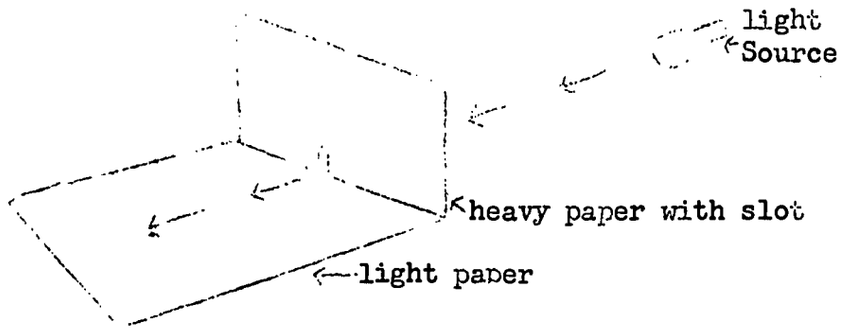
A. Equipment: a drinking straw, source of light

Activity: Look at the light source through the straw and slowly bend the straw. Can you still see the light source? Can you see any light?

B. Equipment: flashlight, small piece of heavy paper small piece of light colored paper, ruler

Activity: Cut a slot 2" high and 1/8" wide in the piece of heavy paper. Place it, slot down, on the piece of light colored paper.

with the flashlight about two feet behind it. Examine the light that comes through the slot. Does it make a straight line on the paper? Check by laying a ruler along the edge of the lighted area.



5. DIFFERENT MATERIALS OBSTRUCT LIGHT BEAMS IN VARYING DEGREES.

a) Transparent materials allow light rays to pass through them undisturbed.

b) Transluscent materials diffuse light beams as they pass through them.

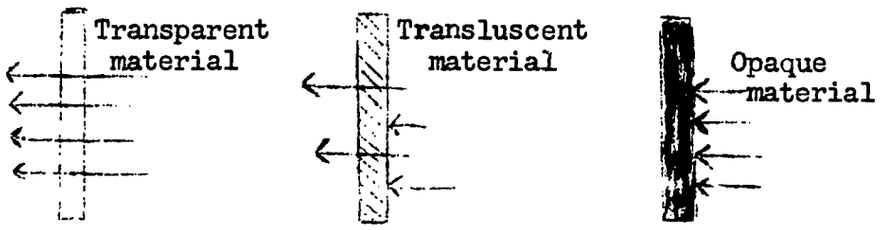
c) Opaque materials do not allow light rays to pass through them.

A. Equipment: glass, paper, wood, paints flashlight

Activity: Put pieces of glass, paper, and wood into the beams of the flashlight. Observe the amount of light which passes through each material.
Put a thin coat of paint on a piece of glass and hold it in the beam of light. Continue applying coats of paint and observe the amount of light coming through the glass.

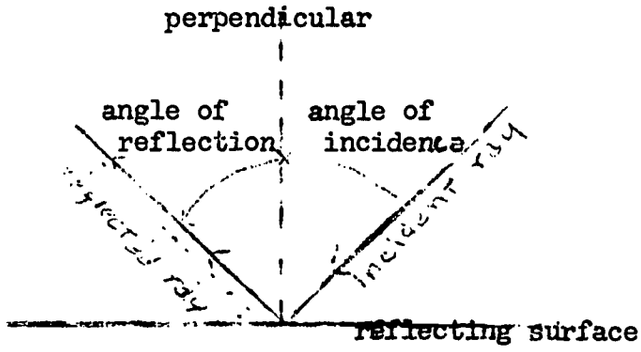
B. Activity: Collect examples of transparent, transluscent, and opaque materials.

C. Activity: Make diagrams showing how light rays act when they strike the three kinds of materials.



6. LIGHT MAY BE REFLECTED FROM SURFACES WITH OR WITHOUT BEING SCATTERED.

Background: The "Law of Reflection" states that, if a light wave strikes a surface from which it will be reflected at an angle, it will bounce off at an angle. The light wave that strikes the surface is known as the incident ray. The angle between the incident ray and a perpendicular drawn to the surface is known as the angle of incidence. The light wave that has bounced off the reflecting surface is called the reflected ray and the perpendicular is known as the angle of reflection. In every case the angle of incidence equals the angle of reflection.



A. Equipment: ball, smooth surface

Activity: Throw the ball against the surface at various angles and observe the angle at which it bounces back.

B. Equipment: flashlight, mirror, two chalkboard erasers full of chalk dust

Activity: Darken the room, lay the mirror on a table, and shine the light on it at a slanting angle. Have someone clap the erasers a foot above the mirror to make the path of light more visible. (Do you know why this technique does so?) Look at the angle made by the flashlight beam and the mirror. Compare it with the angle of the reflected beam.

C. Equipment: flashlight, mirror

Activity: In a dark room put a mirror on the floor. Shine a flashlight on the mirror at various angles and observe the locations of the reflected spots. Compare the light paths

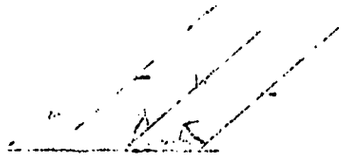
with those of the ball. Notice that in activities B and C the light is reflected as a single beam. This kind of reflection is called regular reflection.

D. Equipment: flashlight, two chalkboard erasers full of chalk dust, piece of rough paper.

Activity: Repeat activity B replacing the mirror with the paper. Notice the paper reflects the light in a spread-apart, or scattered way. This is called diffuse reflection.

E. Activity: Make a diagram illustrating a beam of light reflecting off a smooth surface and one reflecting off a rough surface. Explain why an image cannot be reflected from the latter.

smooth reflecting surface



rough reflecting surface

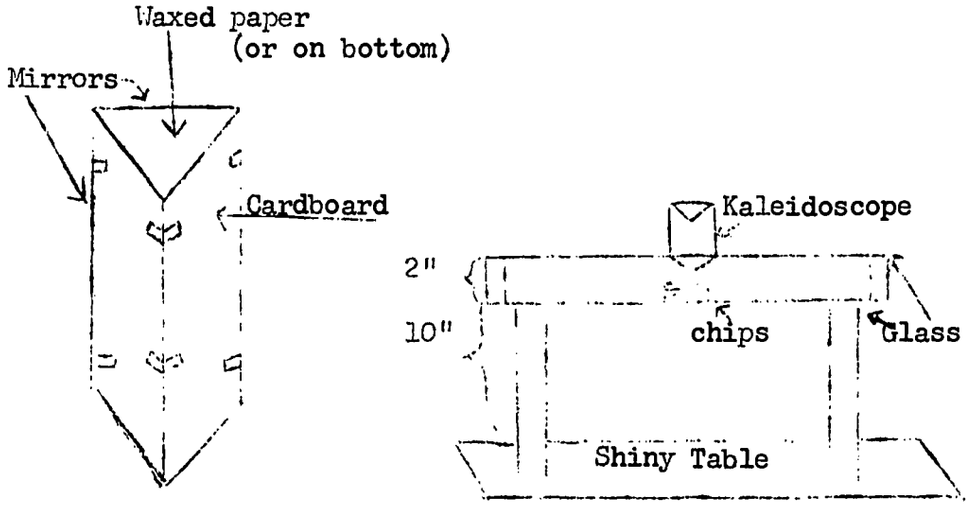
F. Equipment: empty milk carton, two pocket mirrors slightly larger than the width of the carton, sharp cutting tool

Activity: Make a simple periscope and explain how it works. Cut slots in the carton to hold each mirror and square openings for the light to come through.

G. Equipment: two mirrors and one piece of cardboard of exactly the same size and shape, tape, tiny pieces of colored tissue or plastic, small piece of wax paper, piece of glass, shiny surface table or electric light

Activity: Stand the mirrors and cardboard on their shorter edges to form a triangle with the mirrors facing inside. Tape them together and place a small piece of waxed paper over one end. Set the colored chips on the glass about 10 inches above the table top. If the table surface is not shiny put a light under the glass. Hold the mirror triangle about two inches above the chips and look down through the top. You will see many reflections of the chips and, by moving them around on the glass, can create many different patterns. You have made a simple kaleidoscope (a Greek word which means "beautiful images"). Try to find information on kaleidoscopes and their use.

see diagram on the following page.



7. LIGHT MAY BE ABSORBED BY VARIOUS MATERIALS AND CONVERTED TO HEAT ENERGY.

A. Equipment: one piece of black material, one piece of white material, flashlight, sunlight

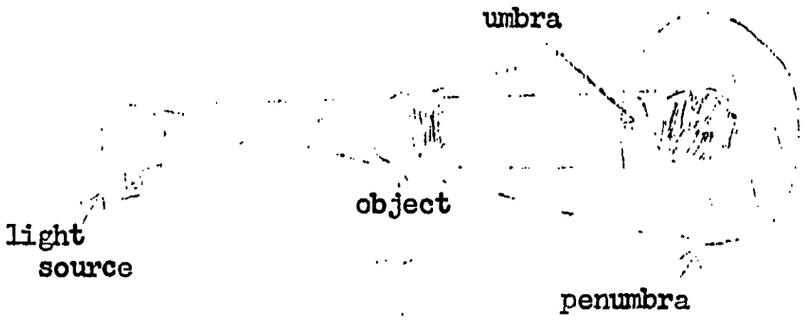
Activity: In a dark room shine a flashlight on the two pieces of material. Which one reflects the most light? Which one absorbs the most?
Place the cloths next to each other in the sunlight for a few hours. Which one feels warmer? Why?

B. Equipment: two identical containers, water, soil or sand, two thermometers, sun

Activity: Fill one container with water, the other with soil. Check to make sure the temperatures are approximately the same. Place the two containers in the sun for several hours. Measure their temperatures. Explain your results. Why is the san on a beach always warmer than the water?

8. SHADOWS ARE PRODUCED WHEN LIGHT SHINES ON OPAQUE OBJECTS.

Background: Multiple shadows are produced by larger sources of light such as electric light bulbs, the sun, or even candles. One shadow is dark and clearly defined while the other is indistinct and blurry. The center or dark sharp shadow, known as the umbra, is caused when all light waves in this area are stopped. The blurry, indistinct shadow, known as the penumbra, is created because not all the light has been completely stopped by the opaque object.



A. Equipment: small intense source of light

Activity: Darken the room and turn on the small light. Observe the shadows that appear, locate the umbras and penumbras, and explain how they are being produced.

B. Activity: Find information on the sundial and how it operates. Try to make a model to demonstrate in the classroom.

9. LIGHT IS REFRACTED WHEN IT PASSES THROUGH CERTAIN MATERIALS.

Background: Light does not travel at the same speed through all materials. Its speed decreases as the density of the material through which it passes increases.
When light passes from one transparent medium to another at an angle, the light waves are bent at the boundary between the two mediums. This bending is known as refraction and is a result of the change in speed.

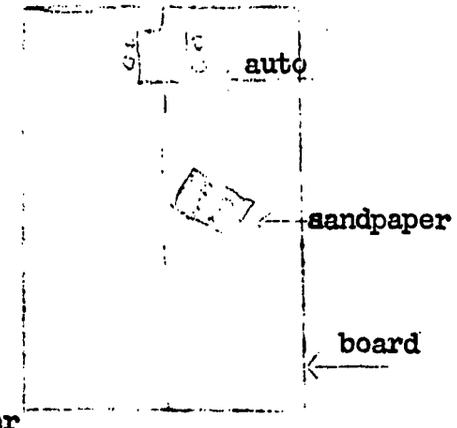
A. Equipment: Three tall jars, water, molasses, three marbles

Activity: Fill the first jar with water and the second with molasses. Drop one marble in each jar and note the speed of each.
Compare the speeds and explain your findings. How does this experiment help explain the motion of light?

B. Equipment: board, small piece of rough sandpaper, toy car

Activity: Glue the sandpaper to the board at a 30° angle to the perpendicular. Place the board so that one end is about one inch higher than the other. Roll the car down the board so that one of the sides will enter the sandpaper before the other. Notice the path taken by the wheels as they enter the sandpaper track and when they leave it.

Think of the wheels as representing a wave of light and the sandpaper as a piece of glass or substance other than air. Repeat the experiment sending all four wheels pass over the sandpaper. Observe the path of the auto and compare it with the previous path. What changes in the auto's speed occurred? Apply these observations and explanation to light refraction.



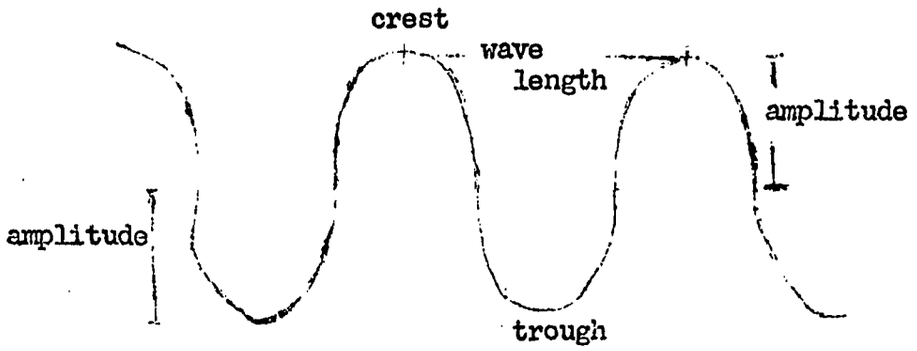
C. Equipment: coin, wax, dish, water

Activity: Put a coin into the bottom of a dish and glue it in place with some melted wax. Stand back far enough to allow most of the coin to disappear from view. Let the side of the dish hide most of the coin. Have a friend pour water into the dish. Describe what happens and explain why.

D. Activity: Find information on mirages and explain how they are formed.

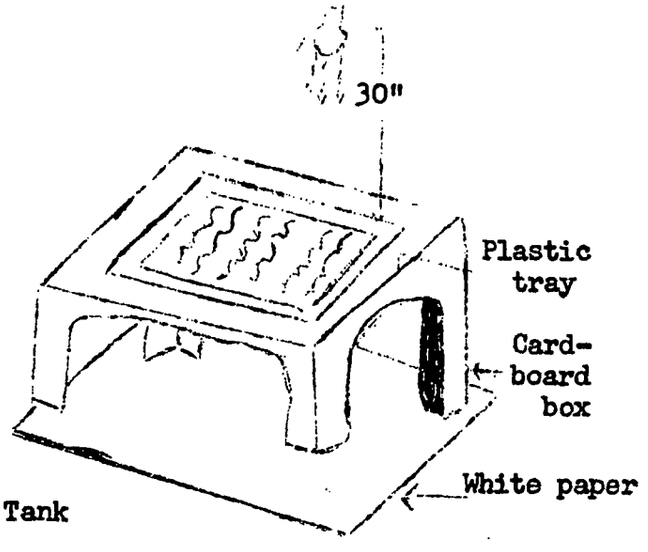
10. LIGHT WAVES HAVE AMPLITUDE, FREQUENCY, AND SPEED.

Background: All waves have certain characteristics which allow us to compare them with each other. The distance from crest to crest (or trough to trough) is called the wavelength. The speed of the waves is the rate at which each crest appears to move. The frequency is the number of crests that pass a given point each second. The amplitude refers to the height of the crests and troughs. The amount of energy carried by waves depends on their amplitude and frequency. The speed of the wave is determined by multiplying the frequency times the wave length.



A. Equipment: large cardboard box, unfrosted light bulb, ruler, transparent plastic container (20" x 10" X 1-1/2"), white paper, level table, water, pin, pencil, paper towels

Activity: Cut large openings in the sides, top, and bottom of the box. Spread a sheet of white paper on the table. Put the box directly over the white paper. Put paper towels along the edges of the plastic container. Place the container on top of the box. Hang the light over the plastic container with 1/8 inch of water. Partially darken the room. Turn on the light over the container. Take the pencil with a pin stuck in the eraser and tap the water surface with the pinhead. Adjust the light so that the shadows of waves show clearly on the paper. Observe the wave shadows made by running your finger through the water in a straight line. Vary the speed of the vibrations and observe the results. Try to determine the speed of the waves in each case.



Ripple Tank

B. Equipment: 15 foot length of rope, doorknob

Activity: Tie the rope to the doorknob. Hold the rope straight out, but leave a little slack. Snap the rope sharply and observe the wave travel along the rope. Try to determine the wave length, frequency, and speed of the waves.

11. LIGHT WAVES TRAVEL AT SPEED OF 186,000 MILES PER SECOND THROUGH SPACE.

A. Activity: Find out how these scientisits measured the speed of light: Galileo, Ole Romer, Albert A. Michelson.

B. Activity: Calculate the distance light travels in one year (186,000X60X60X24X365.25= 5,869,713,600,000.00)

12. SUNLIGHT MAY BE BROKEN UP INTO AN ORDERLY SEQUENCE OF COLORS CALLED THE SPECTRUM.

13. THE COLOR OF LIGHT IS DETERMINED BY THE FREQUENCY OF ITS WAVE.

Background: White light consists of a mixture of all the colors of the spectrum and may be separated into these colors by passing a beam of light through a prism. Violet has the highest frequency, 750,000,000,000,000 per second, (and therefore the most energy) in the spectrum while red has the lowest. Thus, it follows that a blue flame is much hotter than a red one. The color of an object depends on the composition of the object and the light in which the object is viewed. An opaque object will absorb certain colors and reflect the rest. In the sunlight a red apple reflects red light and absorbs the others. Thus, the apple is "red." In blue light, however, the apple appears black since there are no red light waves to be reflected.

A. Equipment: filmstrip projector, small piece of black paper, white paper to use as a screen, one or two prisms.

Activity: Cut a small slit in the black paper and insert it in the film holder to produce a narrow beam of light. Darken the room and hold one prism in the beam until the spectrum is produced on the screen. Notice the sequence of colors and position of the prism.

Hold the second prism between the first one and the screen in such a manner that a white beam is produced on the screen. Notice the position of both prisms and explain the paths followed by the light waves.

B. Equipment: cardboard circle 3 or 4" in diameter, small nail, water colors or crayons, hand drill

Activity: Divide the circle into a "pie" with six pieces. Color each piece following the order of colors as they appear in spectrum. Put a small nail through the center of the color wheel and glue it in place. Set the nail in the hand drill so it can turn freely. Turn the drill quickly until the colors blend and appear white. Explain how this is possible. Try the same experiment with the colors in different orders.

C. Activity: Find scientific explanations for the appearance of rainbows, blue skies, and black space above the skies.

14. VISIBLE LIGHT IS ONLY A VERY SMALL PART OF THE ELECTROMAGNETIC SPECTRUM.

Background: Electromagnetic waves include an enormous range of frequencies and wave lengths and are capable of many effects: radio, television, radar, visible light, x-rays, and gamma rays. Moving from radio waves at one end to gamma rays at the other, the wavelength decreases progressively from about two miles to a millionth of a millionth of an inch. Electromagnetic waves, first described by James Maxwell, are a good example of the basic unity of nature. Waves in various parts of this range do have particular characteristics, but all have many properties in common, notably a speed of 186,000 miles per second in a vacuum.

A. Activity: Find information on the life and work of James Maxwell.

B. Activity: Make a diagram of the electromagnetic spectrum and describe the uses and characteristics of the various types of waves.

C. Activity: Explain the words ultraviolet and infrared. Find information on the locations and uses of these waves in our daily lives.

EXTENSION ACTIVITIES

Students may wish to use their knowledge of light to explain how various optical instruments operate. Cameras, telescopes, microscopes, magnifying glasses, eyeglasses, and the human eye can all be explained using the concepts developed in the unit. Below are a few activities dealing with optics.

Making and Using A Pinhole Camera

Equipment: small carton, open on one side, aluminum foil square 2" x 2", tissue paper, black construction paper, tape

Activity: Cut an opening 1½" x 1½" in the bottom of the camera. Make a pinhole in the square of aluminum foil and tape it over the opening. Cover the open end of the carton with tissue paper. Shade the tissue paper with black construction paper. Point the camera at a well-lighted object. Notice the inverted image and try to expain it. (Remember that light travels in straight lines.)

Making A Simple Telescope

Equipment: two pieces of 18" cardboard tubing, one small enough to fit into the other without allowing light to pass between them, two convex lenses the sizes of the tubings.

Activity: Place the smaller tube inside the larger one and glue the lenses to the opposite ends. The length of the tubing depends on the strength of the lenses you are using. You can determine the exact length by holding one lens in front of your eye and moving the inside tube back and forth until you see an enlarged image of the object at which you are looking. Aim the tubes at an object 10 or 15 feet away in order to determine the length of the tubes.

Studying Images Formed By Convex Lenses

Equipment: lighted candle, convex lense, paper screen

Activity: Place the candle and screen about two feet apart. Darken the room. Move the lense between the candle and screen until the image of the candle appears clearly on the screen. It might be necessary to move the candle closer to the screen. Describe the image formed. Carefully measure the distance from the lense to the screen. This distance is called the focal length. Repeat the experiment with different lenses and measure the focal lengths. Try using a concave lense. Can you explain why no image is formed?

APPENDIX

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Films

Color and Light: An Introduction	Coronet	(11 Min. col. or B & W)
How to Bend Light	E.B.F.	(10 Min. B & W)
Learning About Light	E.B.F.	(8 Min. col. or B&W)
Light All About Us	Coronet	(11 min. col. or b&W)
Light and Color	E.B.F.	(14 min. color)
Light and Shadow	McGraw	(10 min. b & w)
Nature of Light	Coronet	(10 min. col. or b&w)
Reflection:	McGraw	(13 min. b&w)
Science of Light	Churchill	(11 min. col.)

Filmstrips

Light	McGraw	(color)
Light	E.B.F.	"
Light and Color	Jam Handy	"
Light and Color	McGraw	"
Light, Lenses, and Cameras	McGraw	"
Light and How It Travels	Jam Handy	"

Community Resources to Investigate

Local photographers, camera shops, and camera manufacturers for information about photography.

An optician for discarded lenses with which to experiment.

Hardware stores to observe different lighting fixtures and note scientific principles used in their construction.

School building and custodian to learn how the school is lighted and, with a light meter, see how much light is used for various purposes.

WORKSHEET IDEAS

Word Derivations

Many words in our language today have been derived from Latin and Greek words used thousands of years ago. Try to match the words below with their original definitions. Then write the meanings of the words as we use them today when discussing light.

(a) corpuscle (b) diffuse (c) opaque (d) penumbra (e) refract

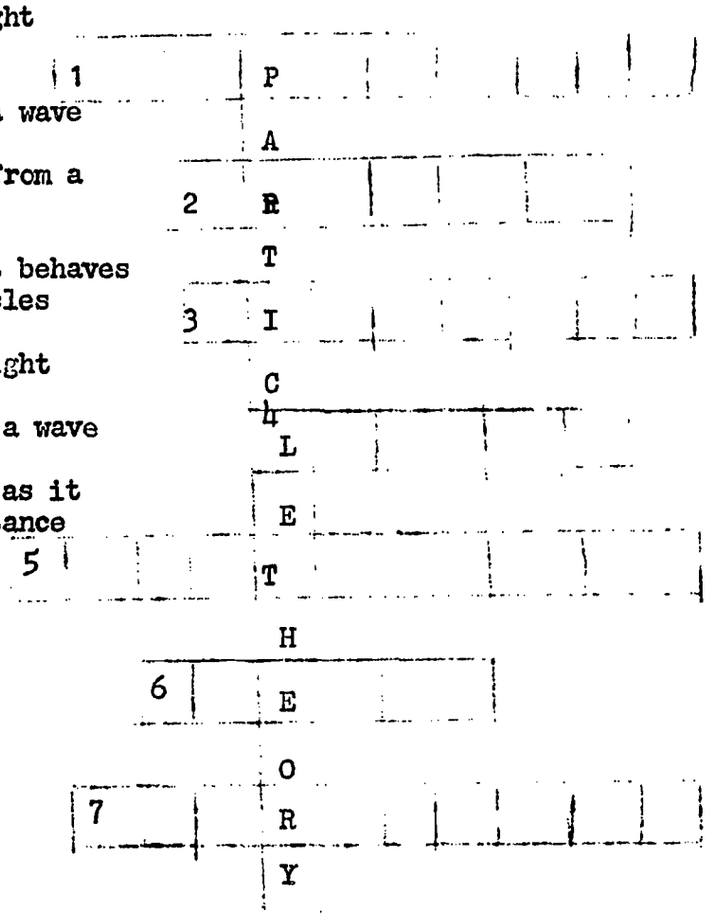
Original meaning	Word	Modern Definition
1. almost a shadow	(Latin)	
2. to pour out	(Latin)	
3. a little body	(Latin)	
4. to break	(Latin)	
5. shady, dark	(Latin)	

Answers: 1 - d, 2 - b, 3 - a, 4 - e, 5 - c

Photo - comes from a greek word which means "light." Try to find as many words as possible that begin with this prefix and give the meaning of each.

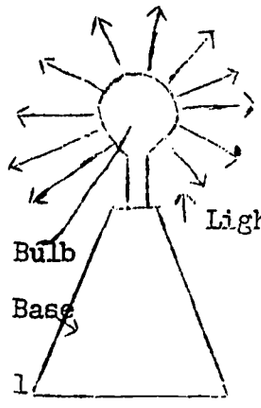
Fill in the Blanks

1. Newton's word for light particles
2. The lowest point of a wave
3. The light reflected from a rough surface
4. A form of energy that behaves like waves and particles
5. Huygen's theory of light
6. The highest point of a wave
7. The bending of light as it passes from one substance into another

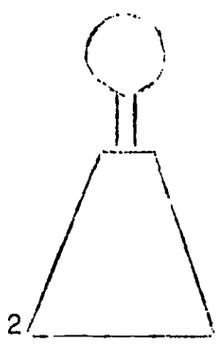


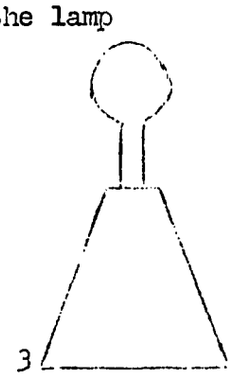
Answers: 1) corpuscles
2) trough
3) diffused
4) light
5) wave theory
6) crest
7) refraction

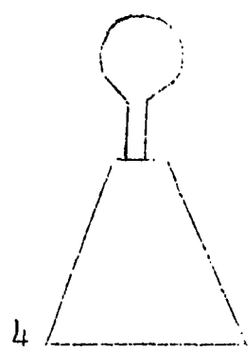
Students might enjoy making their own puzzles using other key words and phrases from the unit.



Put the shade on the lamp



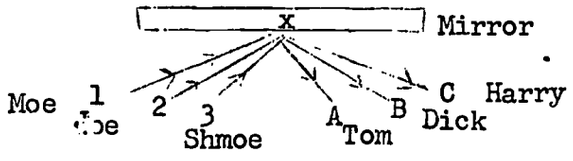




Lamp #1 shows how a light bulb gives off light without a shade on it. Put a transparent shade on lamp #2, a transluscent shade on lamp #3, and an opaque shade on lamp #4. Use a shade with this kind of shape

and remember the top and bottom of it are open. Use arrows to show how the light rays would come from each lamp. Write the kind of material you would use for each shade at the base of the lamp.

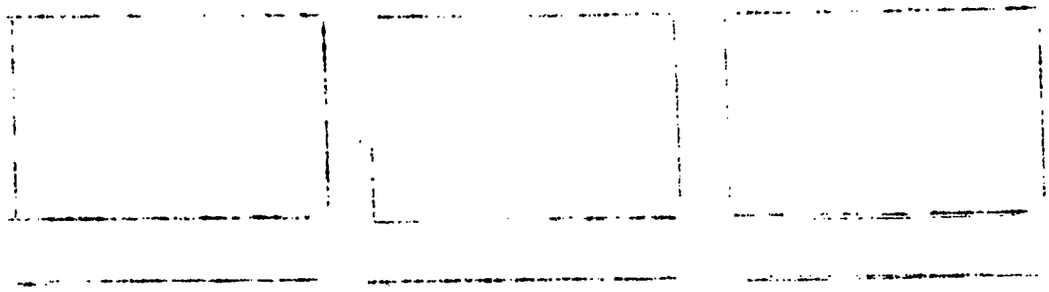
Reflection of Light



Tell who Moe, Joe, and Shmoe will see when they look at point X on the mirror and explain why. Who will Zelda see if she stands between Shmoe and Tom?

Turn this paper over and divide it into 4 parts. Label them 1) TRANSPARENT OBJECTS, 2) TRANSLUCENT OBJECTS, 3) OPAQUE OBJECTS THAT ABSORB LIGHT, and 4) OPAQUE OBJECT THAT REFLECTS LIGHT. Choose one room in your home and look at all the objects in it very carefully. Then list them on the proper part of your paper. Example - chair would be listed under part 3.-OPAQUE OBJECTS THAT ABSORB LIGHT.

In the boxes below draw pictures of: a) light rays bouncing off a smooth surface; b) light rays bouncing off a rough surface; c) light rays going through water. Use the correctterm to label each one.



Define the words below and give two examples of each one.

OPAQUE

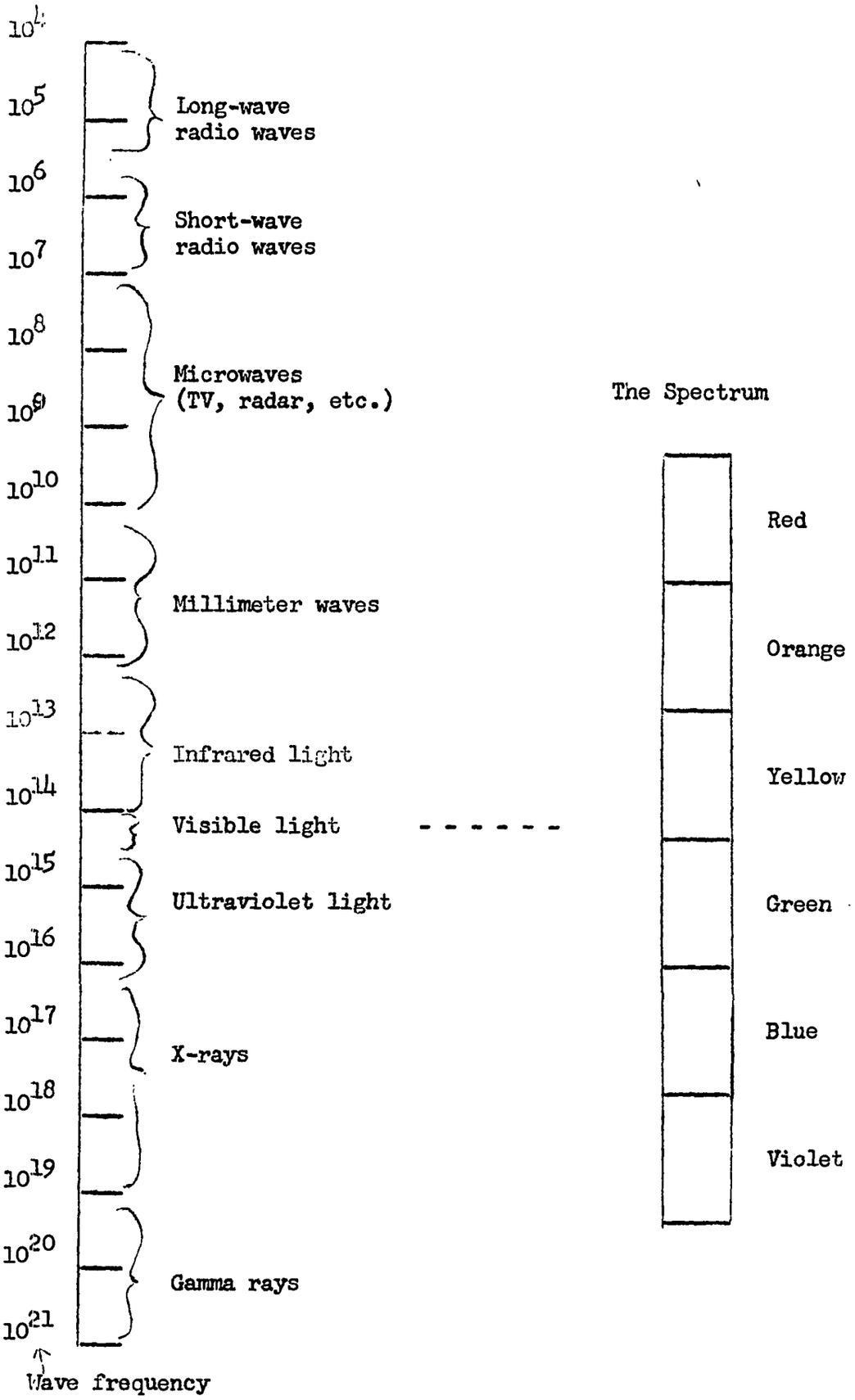
TRANSPARENT

TRANSLUSCENT

Name two man-made sources of light and two natural sources of light.

How do we see different colors?

THE ELECTROMAGNETIC SPECTRUM

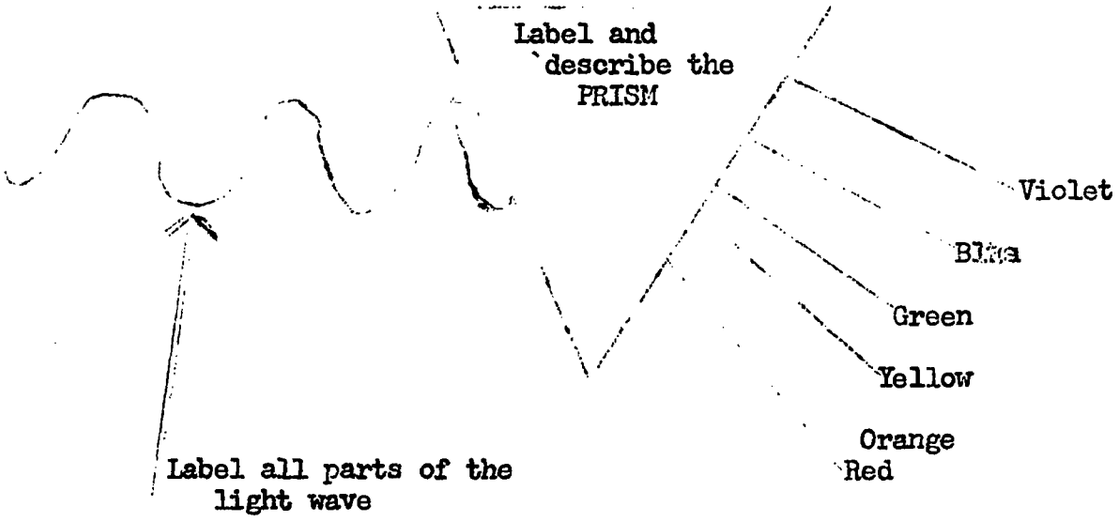


Bulletin Board Ideas

STRANGE SOURCES OF LIGHT - Have students collect strange light sources to display and explain. Old light bulbs, kerosene lamps, and fireflies are a few examples.

CLEAR TO CLOUDY - Have students collect transparent, transluscent, and opaque materials. Arrange them in order from the "clearest" to the cloudiest."

LIGHT AND COLOR



PHOTOSYNTHESIS

Overview

This unit describes the steps taken during photosynthesis and the importance of this process for all life on earth. It is intended to be taught in the spring preceding the unit discussing ecology. The final concept presented in this unit may serve to introduce that unit if the teacher desires.

Many activities presented provide an excellent opportunity for students to practice the scientific methods and skills required for successful, accurate results. In experiments using a variable, care should be taken that the constants are equal. Close observations and detailed records should be kept of changes that occur during each experiment. (See Appendix for a sample data sheet.)

Because many of the activities take several days to complete, the teacher may wish to initiate more than one at the same time. Often an activity suggested with one concept may be used to demonstrate and reinforce other concepts.

CONCEPTS TO BE DEVELOPED

1. Unlike men and animals, plants have the ability to produce their own food by means of a process called photosynthesis.

2. Water, one of the necessary ingredients in photosynthesis, enters the plant through its roots and rises through the stem to reach the leaves where photosynthesis takes place.

3. Leaves "breathe" by means of very tiny openings called stomata.

    a. Leaves breathe in carbon dioxide, another necessary ingredient in photosynthesis, through the stomata.

    b. Leaves breathe out oxygen and water vapor through these same stomata.

4. Chlorophyll, a green chemical which gives the leaf its color, is found in the cells of leaves and is another necessary ingredient in photosynthesis.

5. Light energy is necessary for the production of chlorophyll.

6. During photosynthesis carbon dioxide and water combine to form a sugar called glucose in this manner:

$$6\ CO_2 + 12\ H_2O \qquad 1\ C_6H_{12}O_6 + 6\ H_2O + 6\ O_2$$

7. The glucose produced in the leaves is stored by the plant as starch and converted into food for itself and man.

8. The photosynthesis process which takes place in all green plants makes them an important link in the carbon dioxide cycle.

APPROACH TO INTRODUCING THE UNIT

A few rather startling statistics about leaves might serve as a good interest arouser and stimulator in the study of these seemingly insignificant, numerous green things. Perhaps a "Who Am I? bulletin board could display facts such as:

1. I (along with some friends) can give off one ton of water a day. (An elm tree gives off this amount each day.)

2. One square inch of me sometimes contains 100,000 holes. (An oak leaf has 100,000 stomata per square inch.)

3. I (along with all my friends) can produce 400,000,000,000 tons of sugar a year. (Scientists estimate that all the earth's plants produce this amount of sugar in one year.)

4. Without me there would be no other life on earth-including you.

5. The dictionary says I am a lateral outgrowth from a stem that constitutes a unit of the foliage of a plant and functions primarily in food manufacture by photosynthesis.

Do You Know Who I Am?

1. UNLIKE MEN AND ANIMALS, PLANTS HAVE THE ABILITY TO PRODUCE THEIR OWN FOOD BY MEANS OF A PROCESS CALLED PHOTOSYNTHESIS.

Background: Photosynthesis is the process by which, with the energy of light, plants combine water and carbon dioxide, producing a type of sugar and oxygen. The plant cells are able to change the sugar into starch for storage or combine it with other materials to build substances such as proteins and vitamins. Sugar can also be converted into fats. Thus, this sugar-making process in green plants produces the primary material of all foodstuffs.

The word photosynthesis is made up of two words that emphasize the key aspect of the action: photo, which means "light," and synthesis, which means "putting together." "Putting together by means of light" is exactly what happens in the food-making process.

A. Activity: Discuss the differences in raising a plant and an animal and the various ingredients required by each to live. An animal needs water and food while the plant must have water, soil, and sun. Soil and sunlight are not "foods" in the sense that they do not bring direct nourishment to a living object. Therefore, the question arises, "Where does the plant's food come from?"

B. Activity: Discuss the word photosynthesis and its possible meanings. Recall the meaning of the prefex photo and familiar derivatives of synthesis, e.g., synthetic and synthesize.

2. WATER, ONE OF THE NECESSARY INGREDIENTS IN PHOTOSYNTHESIS, ENTERS THE PLANT THROUGH ITS ROOTS AND RISES THROUGH THE STEM TO REACH THE LEAVES WHERE PHOTOSYNTHESIS TAKES PLACE.

A. Equipment: radish or corn seeds, moist paper toweling or blotting paper, dish, glass cover, magnifying lense, red ink or food color

Activity: Put the seeds on moist paper in the dish and cover them. Keep the paper moist. After a few days when the young seeds have sprouted examine them with a magnifying lense. Notice the roots and tiny root hairs on the roots. Now observe how water soaks into the root hairs by adding a few drops of red ink or food color to the water used to moisten the plants. You will see the roots absorb the colored water.

B. Equipment: stalk of celery with leaves, red ink or food colorings, water, drinking glass, pocketknife.

Activity: Put water in the drinking glass and color it with the ink or food coloring. Cut a small slice off the celery stalk and set in in the water in a sunny window for several hours. Cut open the stalk and notice how the red water has passed up the tubes toward the leaves.

You might wish to repeat this experiment using several pieces of celery and placing some in a refrigerator and comparing their rate of flow with those at room temperature. You will notice that water moves up the stem faster in warmer temperatures.

C. Activity: Examine the vein structure of various leaves. Notice how the main vein (called the midrib) branches off into smaller ones which, in turn, continue to branch until they become invisible to the naked eye.

3. LEAVES "BREATHE" BY MEANS OF VERY TINY OPENINGS CALLED STOMATA.

a. Leaves breathe in carbon dioxide, another necessary ingredient in photosynthesis, through the stomata.

b. Leaves breathe out oxygen and water vapor through these same stomata.

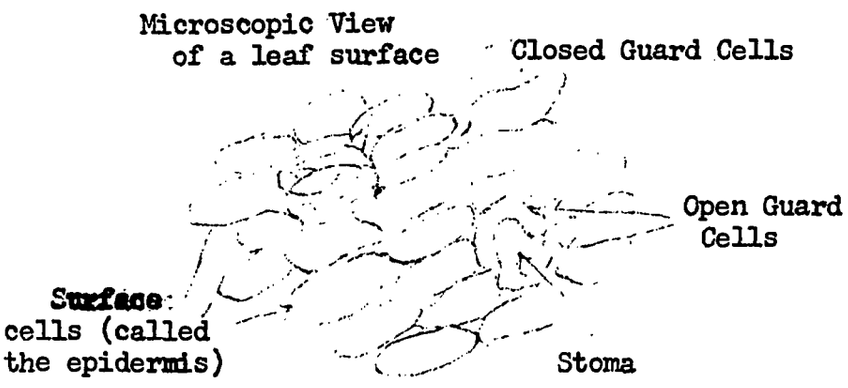
Background: The word stomata (singular-stoma means "little mouths." Actually they are tiny air holes in the underside or floor of the leaf and act like valves opening and closing to bring in carbon dioxide and give off water and oxygen. On either side of the stomata are guard cells. Changes in sizes of these guard cells cause the stomata to open and close in darkness. There are countless numbers of stomata - many thousands to the square inch of the leaf surface. For example, an apple-tree leaf may have 47,000 stomata in a square inch of its lower surface, a poplar leaf 18,000 and an oak leaf over 100,000.

The process of giving off water through the stomata is called transpiration. The leaf acts somewhat like the nozzle of a garden hose, spraying out invisible water vapor through the stomata. Because there are so many leaves (a large elm has several million), the amount of water a tree collects from the ground and delivers to the air is enormous. An elm may give off a ton of water a day.

A. Equipment: outside lettuce leaves, tweezers, water, glass microscope slide, cover glass, and microscope.

Activity: The side of the lettuce leaf which faces outside is the underside of the leaf. Gently break the leaf toward the outside and you will find the thin, outside layer of leaf hanging from the broken edge like very thin paper. With tweezers pull off a very small piece of this outside layer. Place it in the center of the glass slide, put a drop of water on it, and cover it with the cover glass. Observe the specimens under the microscope and look for cells surrounding small holes or openings. These are the stomata and guard cells.

(Note: This same equipment will be used in a later investigation - Concept #4, A)



B. Equipment: large, fresh leaf, two glasses of equal size, square of heavy cardboard, Vaseline

Activity: Fill one glass with water. Coat the rim with Vaseline and put the cardboard on top. Cut a small slit in the center of the cardboard and push the stem of the leaf throughtthe slit. Waterproof the slit by covering it with Vaseline so that no water can pass through the cardboard or the slit. Coat the rim of the second glass with Vaseline and put it upside down on the cardboard. Put the glasses to one side, and then look at them after four or five hours. There will be droplets of water in the upper glass. It is water that the leaf has "drunk" from the bottom glass and has then given off through tiny holes in its stomata.

C. Equipment: large fresh leaves, glass of warm water

Activity: Place some leaves under the surface of the water and wateh carefully for the presence of bubbles in the water given off by the leaves. Squeezing the sides of a leaf together in a fold should force out more bubbles. Note that these bubles are oxygen which the leaves are "breathing out."

The same experiment may be performed in cold water and compared with the first one. Fewer bubbles will be produced.

(Note: This is the second experiment (Concept 2, B) in which warm surroundings have speeded the reaction time. Thus it becomes clearer why plants grow quickly when warm weather arrives.)

• Equipment: radish seeds, several baby food cans filled with damp soil, two large glass jars with tight fitting lids, ¼ cup diluted vinegar (50% water), baking soda, masking tape

Activity: Plant radish seeds in the cans. After the seedlings are growing select two cans with healthy seedlings of comparable size and put one in each of the glass jars. In one of the jars place another can containing the vinegar. Add small amounts of baking soda, to the liquid until it no longer fizzes. Then screw the lids on both jars tightly and seal them with masking tape. Place them in the sunlight and observe their daily growth rate. In time the seedlings in the jar with ordinary air should show a smaller and less vigorous growth than those in jar with air enriched by carbon dioxide from the vinegar and baking soda. Since plants need carbon dioxide to produce food, the plant receiving more carbon dioxide will grow larger than the plant receiving less.

4. CHLOROPHYLL, A GREEN CHEMICAL WHICH GIVES THE LEAF ITS COLOR, IS FOUND IN THE CELLS OF A LEAF AND IS ANOTHER NECESSARY INGREDIENT IN PHOTOSYNTHESIS.

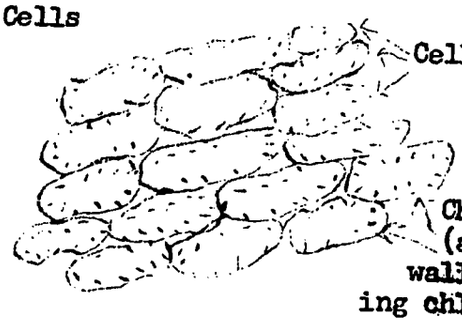
Background: The word chlorophyll comes from a Greek word meaning "light-green leaf." It is found as tiny specks against the inside walls of leaf cells in such numbers as to give the leaf its green color. The function of the chlorophyll is that of a catalyst. That is its presence is necessary as a participant in forming a union between water and carbon dioxide, of which, however, it does not become a part.

Comparing the leaf to a factory sometimes helps explain the funcion better. Water and carbon dioxide are thus the raw materials while the chlorophyll acts as machinery. As will be seen later, light or sunlight is the source of power nedded to operate the machinery.

A. Equipment: Same as that used in investigation A, Concept #3

Activity: Look for small green particles inside the cells of the leaf. These particles are called chloroplasts and contain the chlorophll found in the leaf.

Microscopic View-
Inner Leaf Cells



B. Equipment: spinach leaves (or other green leaves), acetone (rubbing alcohol or nail polish remover may serve as substitutes), electric blender, strainer, few test tubes (number depends on amount of liquid obtained), strips of white blotting or filter paper, glass bottle with lid

Activity: Crush the leaves in the blender until they are in a pulp state. Pour some acetone into the blender, allow the leaves to soak a few minutes, and turn the blender on again. Allow the leaves to settle for a short time and strain off the green fluid into the glass container and cover it.

Depending on the amount of liquid collected, work in teams with test tubes containing ½ inch of the green liquid and strips of blotting paper. Place each strip in the liquid and let it remain suspended in the tube while the liquid creeps up the strip. If the activity is successful a graduation of color (deep green at lower end, lighter green in middle, yellow green near top) should appear at the edges of the strip near the top. You have separated some of the pigments from the leaf. The yellow fringes are an indication of the pigment carotene.

5. LIGHT ENERGY IS NECESSARY FOR THE PRODUCTION OF CHLOROPHYLL.

A. Equipment: several sprouted bean seeds, milk cartons or other containers filled with soil

Activity: Sprout the seeds in total darkness. After they have grown for a few days take some of them out of the dark environment and place them in a sunny area while the rest of the plants remain in darkness. Make predictions concerning the growth and life span of the two groups and explain your reasoning.

Continue to care for the plants until those in the dark environment die. Compare the colors in the leaves and explain the differences. Which leaves have lost the chlorophyll? What was the one missing ingredient in their development? You can now see that light is essential in the production of chlorophyll.

This same activity may be done using small sweet potatoes in tumblers partially filled with water. Only part of each potato should be under water.

B. Equipment: several onions and potatoes that have sprouted in a dark place, a constant source of artificial light (e.g. strong flashlight)

Activity: Put some of the potatoes and onions under artificial light and the rest in sunlight. Observe changes occurring in the sprouts of each group and compare them. Explain the green color that is appearing in them.

C. Equipment: radish seeds, flower pot filled with soil, cardbonrd box, large enough to cover the flower pot garden, with one side removed

Activity: Plant the radish seeds in the pot and keep the soil damp. When seedlings emerge cover them with the cardboard box so they receive light only from one direction. Observe the direction of growth for a few days. Turn the flower pot around and observe the results after another few days. The seedlings as you see will always grow toward the light, their source of power.

6. DURING PHOTOSYNTHESIS CARBON DIOXIDE AND WATER COMBINE TO FORM A SUGAR CALLED GLUCOSE IN THIS MANNER:

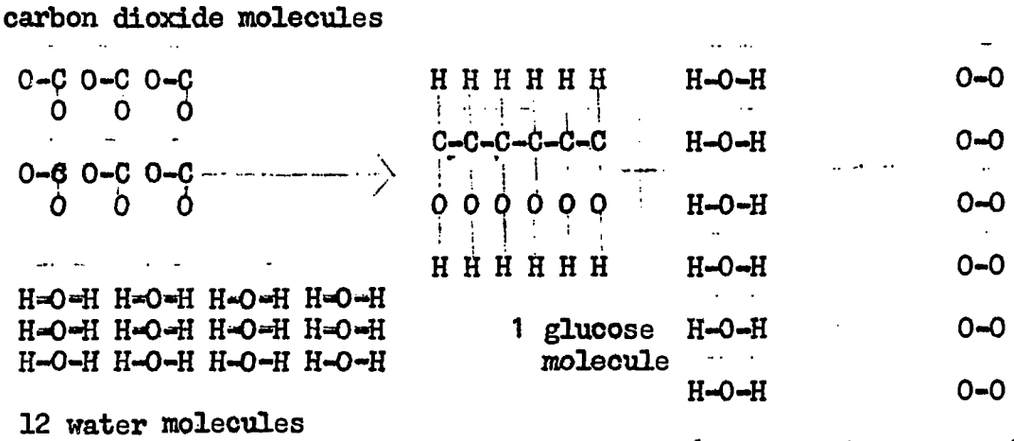
$$6\ CO_2 + 12\ H_2O \rightarrow 1\ C_6H_{12}O + 6H_2O + 6O_2$$

Background: The above chemical equation is read: 6 molecules of carbon dioxide plus 12 molecules of water yield one molecule of glucose plus 6 molecules of water plus 6 molecules of oxygen. Note how this equation is balanced. On the left side of the arrow are six carbon atoms, 24 hydrogen atoms, and 24 oxygen atoms. The same number of each is found on the right side only in different combinations.

During photosynthesis the energy of the sun is used to break the water molecule apart into hydrogen and oxygen. The hydrogen then combines with the carbon dioxide to from glucose and the oxygen escapes through the stomata. A great deal of energy is required to split the water molecules apart. This energy, which comes from the sun, is transferred to the plant to be later used and is therefore, another important product of photosynthesis.

A. Equipment: marbles, stones or buttons of three colors; black, white, and green, glue, heavy poster paper

Activity: Make a model of the chemical equation showing photosynthesis, using black objects to represent carbon, white for oxygen, and green for hydrogen. Be sure to label all ingredients and show how they are rearranged to form new products.



B. Equipment: balloon, "lots of hot air"

Activity: A plant stores energy in the ssme manner as a ballon. Blow up the balloon and tie the end securely. Notice that you used energy to do the job. Where is this energy now located? How would this energy be used by the balloon if you suddenly untied the end? Can you sed how energy was transferred from you to the balloon? Energy is transferred from the sun to a plant in the same manner when the water molecules split apart and glucose is formed. How do you think the plant will use its energy?

C. Activity: Try to find more information about the sugar glucose.

7. THE GLUCOSE PRODUCED IN THE LEAVES IS STORED BY THE PLANT AS STARCH AND COVERTED INTO FOOD FOR ITSELF AND FOR MAN.

Background: Glucose may be easily broken down and therefore gives off much of its stored energy which is used by the plant for growth and the production of other foods. Glucose that is not immediately used is stored in the leaves as starch because starch does not dissolve in water as sugar does. When the plant needs more energy the starch is reconverted to sugar, dissolved in water, and carried by this sap to other parts of the plant. Glucose, a sugar, and starch belong to a class of chemical compounds called carbohydrates (carbo - containing carbon, hydrate - containing water). A molecule of sugar breaks apart into a molecule of starch and a molecule of water.

$$C_6H_{12}O_6 \qquad C_6H_{10}O_5 + H_2O.$$

All plants convert some of their sugar to fat in varying amounts depending on the plant. Peanuts, beans, nuts and avocados all contain a great deal of fat. Fats, like carbohdrates, contain carbon, hydrogen, and oxygen but in different proportions (e.g. $C_{57}H_{104}O_6$).

Plants also convert some glucose to proteins, one of our most important foods. Plants are the earth's only producers of proteins. Along with carbon, hydrogen, and oxygen, proteins also contain nitrogen and often sulfur.

A. Equipment: blown-up balloon from previous experiment

Activity: Recall the energy required to blow the balloon up to its present state. Remember this action can be compared with splitting the water molecule in a leaf. Now untie the balloon. Is it now taking in energy or releasing it? How is it using this released energy? The balloon releasing air and stored energy can be compared to the plant converting glucose to other subatances. Little energy is needed to break apart the glucose molecule so most of the stored energy can be used for plant growth and the production of other foods.

B. Equipment: heat source, small container of alcohol in a larger container of water, Iodine, leaf

Activity: Boil the alcohol over the boiling water (to prevent any accidents since alcohol burns very quickly). Put the leaf in the boiling alcohol until the chlorophyll boils out of it and the leaf appears white. Take the leaf out of the container and put a few drops of iodine on it. A blue color indicates that starch is present. This is the starch that has been converted from the glucose to be stored in the plant.

C. Equipment: plain unsalted crackers

Activity: Chew the cracker slowly without swallowing for a few minutes. You should begin to notice a sweet taste. The cracker is mainly starch while your saliva is mostly water. Use this chemical equation to explain the change in taste: $C_6H_{12}O_6$ $C_6H_{10}O_5 + H_2O$
(glucose) (starch) (water)

D. Activity: List some plants that contain large amounts of fat and find out where they store it and in what form they store it. (Some plants store fat in liquid form while other store it as a solid.)

E. Equipment: burning candle, feather, tongs, small amounts of beans, peanuts, apple, sugar, cheese, raw meat

Activity: Burn the feather and note the odor produced (something like burned meat or singed hair). Foods that contain protein have the same odor when burned. Test your foods for the presence of proteins. You may wish to use a food chart to check your results.

8. THE PHOTOSYNTHESIS PROCESS WHICH TAKES PLACE IN ALL GREEN PLANTS MAKES THEM AN IMPORTANT LINK IN THE CARBON DIOXIDE CYCLE.

Background: The verb cycle means to move around in a circle. When events occur in a cycle, a certain number of actions take place in a definite order without stopping and are dependent upon each other. In nature a cycle enables a limited amount of raw materials to supply processes which never stop. The processes of nature are complimentary. What one builds up another tears down, and what one combines another breaks asunder, Thus, the materials go around and around, being used over and over through the ages.

Photosynthesis combines water, carbon dioxide, and energy, forming sugar and releasing oxygen. Respiration combines sugar and oxygen, producing water, carbon dioxide, and energy. Thus can be seen the carbon dioxide cycle in action.

A. Equipment: two groups of 5-6 willing volunteers, two books

Activity: Have one group stand in a straight line while the other group forms a circle. One member of each group takes a a book and passes it to the right to the next group member. Which group forms the cycle? When will they stop passing the book? Notice their activity will continue until a member stops the action. The group standing in a line had no choice in the matter.

B. Equipment: limewater, goldfish, small clear bowl

Activity: Place the goldfish in the bowl filled with limewater for a few minutes and observe the appearance of the limewater. A cloudy or milky appearance indicates the presence of carbon dioxide. Do fish exhale carbon dioxide?

Breathe into a small amount of clear limewater. Compare it with the results above.

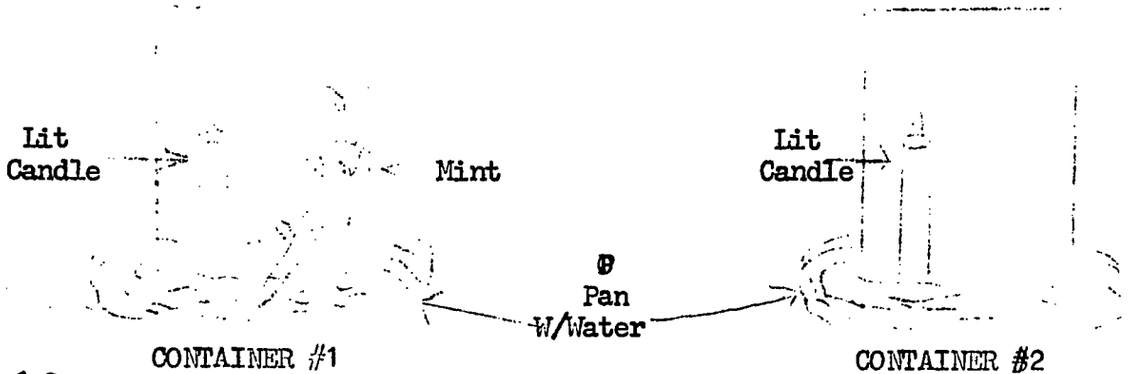
C. Equipment: candle, pie plate, quart jar, small glass, lime water

Activity: Attach the candle to the pie plate with melted wax. Place a small glass of limewater next to the candle. Light the candle and put the jar over the glass and candle. After the flame goes out let the jar stand in place and watch the limewater. Move the pie plate back and forth gently as you do. What happens to the limewater? Why?

The same experiment can be repeated using wood shaving in place of the candle. Compare the results. How does combustion aid plants?

D. Equipment: two candles, two pans, water, two glass jars, sprig of mint

Activity: Attach the candles, by means of melted wax, to the bottoms of the pans and place an inch of water in each pan. Light the candles. Cover one pan with a glass jar. Turn a glass jar over the other but before covering it place a sprig of mint to one side away from the flame. Add another inch of water of each pan, making sure the mint stems are in water while the leaves are above water. Place the equipment in good light, but not in direct sunlight, for several days. Record daily changes in the units. Explain the events in each jar using your knowledge of fire and leaf structure. Describe how the experiment would resulted if leaves did not breathe or if they exhaled carbon dioxide.



E. Activity: Find information about the work of Joseph Priestly and the experiments he devised. If possible, set up a similar experiment in the classroom.

F. Activity: Make a diagram illustrating the carbon dioxide cycle.

Extension Activities

A. Explain why leaves turn colors in the autumn and fall from the trees. Name the other chemicals besides chlorophyll, which are found in the leaves and are responsible for different colors. Try to find examples of them.

B. Find information on, and pictures of various groups of plants that might obtain products needed for photosynthesis in rather strange ways. Some interesting groups might be: desert plants (e.g. cactus); water plants (algae, elodea, seaweed); and cold climate plants.

C. Learn how our bodies use carbohydrates, fats, and proteins. Make a chart showing which plants contain large amounts of each.

D. Try to find the chemical formulas for various kinds of sugar, such as sucrose, fructose, lactose, etc. Explain where each one is found and how it is used. Be sure to include information on artificial sweeteners that are used in many diet beverages and foods.

E. Report on the lives and work of famous botanists and chemists who have studied photosynthesis.

APPENDIX

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"Photosynthesis." Vol. 14, 382.
"Plants." Vol. 14, 470-489.

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---------- Up Above and Down Below. Scott, 1943/

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Films

Photosynthesis: Chemistry of Food Making	Coronet	(11 min. b & w)
Plants Make Food	Churchill	(11 min. color)
The Sun and How It Affects Us	Coronet	(10 min. color)
What Plants Need for Growth	EBF	(11 min color)

Filmstrips

How a Plant Grows	McGraw
How a Plant Makes Food	"
Climates and Plants	2 - 22 - E6
Green Plants	3 - 2 - C4
Living Things Need Other Living Things	3 - 2 - C5
Plants and Parts	3 - 1 B8

Worksheet Ideas

Below is a form which may be used (with modifications) to record data for various experiments throughout the unit.

Data Sheet # --------

Object Under Observation - (description of plant, seed, leaf, etc. as to its color, size, etc. at beginning of experiment)

Surrounding Environment - (amount of water, light, heat, soil, etc. in which the object is living)

Time — Description and Changes in Appearance

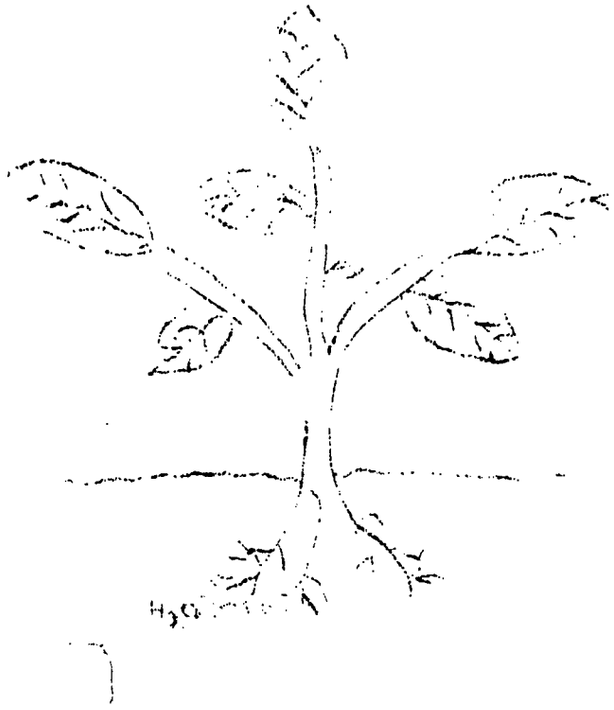
date and hour

Summary - (how the object changes from the beginning to the end of the experiment)

Conclusions - (factors which affected the object; explanations for the changes - or absence of change)

Tracing Water Through a Plant

Directions - In the drawing below trace the path a molecule of water might take as it travels through the plant. Explain what happens to it during photosynthesis. Label all parts of the plant that are used.



Answer - The path of water begins in the root hairs and proceeds through the roots, stem, and veins of the leaf. During photosynthesis in the leaf it separates into hydrogen and oxygen. Hydrogen combines with carbon dioxide to form glucose while oxygen enters the air through the stomata.

Bulletin Board Ideas

Nature's Water Systems - Have students bring in various kinds of leaves and roots to display. Some student might wish to "devein" their leaves. Using a sharp knife and steady hand, it is possible to cut away much of the blade (green section) leaving the vein system bare.

The Leaf As A Food Factory - The leaf itself is the building, chlorophyll is a green machine inside, carbon dioxide and water are the raw materials entering the factory, the sun is the source of power operating the machine, and oxygen, water, and glucose are the finished products leaving the factory.

BALANCE AND DISBALANCE IN NATURE

OVERVIEW

This unit is divided into two separate, but related sections. The first part deals with the science of ecology and stresses the balances and interdependence existing throughout nature. Children are usually aware of this condition but not in a conscious manner so as to influence their actions outdoors. The second half of the unit discusses one means man has been using to upset the balance in nature and harm its members. It is hoped that a discussion of the facts and figures about air pollution will help students realize the dangers in careless action and necessity of conservation. They should be encouraged to investigate other threats to nature presented by man and how they, as individuals or a group, can help alleviate these threats.

APPROACHES TO INTRODUCING THE UNIT

The previous unit has already pointed out to students one type of interdependence existing in nature. Discussions of natural catastrophes (e.g. forest fires, floods, drought, etc.) might arouse student's interest in knowing exactly how many forms of life are endangered from such an event. Seeing the extent of the damage should lead to queries on why so many things are influenced by one sometimes seemingly isolated incident. Thus, the interrelationships and interdependences of life are being revealed.

CONCEPTS TO BE DEVELOPED

Part 1

1. Every organism is affected by all that surrounds it - whether living or non-living - and in turn has some effects on its surroundings.

2. Organisms move into and out of their immediate environment, but eventually these environments reach a STATE OF BALANCE.

3. Man, more than any other factor, has changed the balances existing in nature and often entirely destroyed them.

4

Part II

1. When the composition of air is changed by the addition of substances that are harmful to living things, the air is said to be POLLUTED. The substances are called POLLUTANTS.

2. Although air may be polluted by natural events (e.g. dust storms, volcanic eruptions, forest fires), most pollutants are the result of man's activities.

3. The size of pollutant particles helps determine how long they will remain suspended in the air.

4. Though equal amounts of pollutant material may be discharged into the atmosphere daily, the amount of noticeable air pollution depends greatly on the weather, and it, in turn, has a definite effect on weather conditions.

5. Many pollutants in the air are known to have harmful effects on living things.

6. Special methods have been developed to measure the different kinds of air pollutants.

7. Since no way is yet known to remove pollutants from the air, pollution can be controlled only by preventing them from getting into the air.

PART I - BALANCE IN NATURE

1. EVERY ORGANISM (LIVING THING) IS AFFECTED BY ALL THAT SURROUNDS IT-WHETHER LIVING OR NONLIVING - AND IN TURN HAS SOME EFFECTS ON THE SURROUNDINGS.

Background: Ecology, sometimes called the "queen of the sciences" is the study of the interrelations and interdependence of all living things. The word ecology comes from two Greek words meaning "study of the home, or surroundings."

These interrelations and interdependence can be seen in the carbon dioxide cycle previously discussed, the water cycle, and the mineral cycle. Food Chains are another interesting example of the principle. A food chain is often spoken of as "what eats what." In general, the larger animals eat the smaller, and so on down the line until one arrives at the microscopic animals and plants. Each community has its own particular food chain. One such food chain is diagramed as follows: plants → field mice → weasels. The arrows are read: "are eaten by." In this example, plants are eaten by field mice that are later caught and eaten by weasels. This is a common food chain in grasslands and abandoned fields. In such a food chain, the total weight of organisms at each level decreases from producers through consumers. For example, in ten acres of a typical abandoned field, there would be about 150,000 pounds of plants, 50 pounds of field mice, and only one pound of weasel.

All food chains in a community are not separate and unrelated. They form what is known as a food web, which shows the complex pattern of food relationships of a community. The decomposers shown at the bottom are mainly bacteria and fungi. They decompose, or break down, the bodies of dead organisms and release substances which are then used by green plants.

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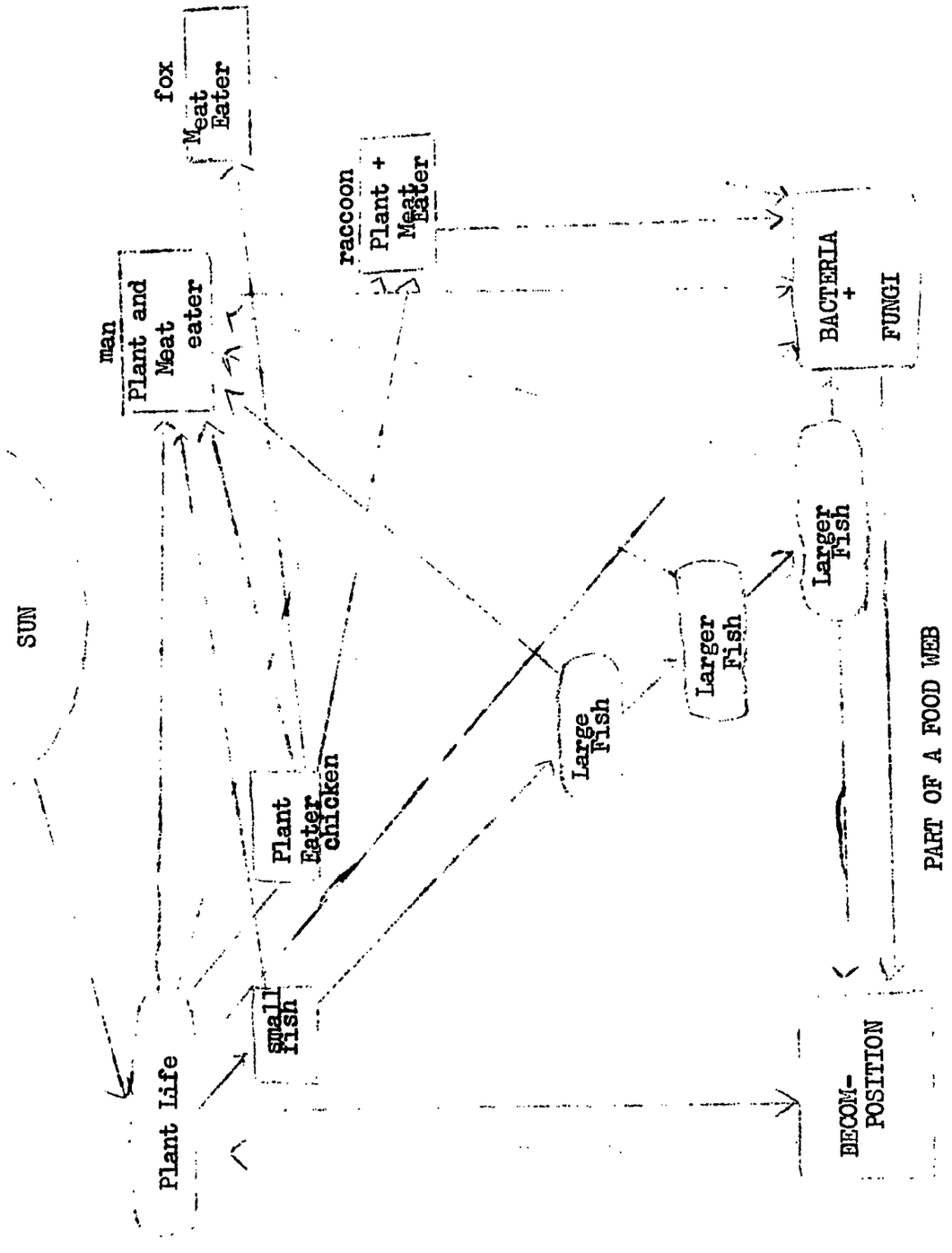


PART OF A FOOD WEB

A. Activity: Review the carbon dioxide cycle discussed in the unit on photosynthesis and show how each participant in it depends upon other participants.

B. Activity: Review the water cycle (discussed in previous years) and how it relates to the carbon dioxide cycle. What element is present in water and carbon dioxide? Is it possible that this element could at one time be an ingredient in carbon dioxide, and at another time an ingredient in water?

C. Activity: Find out what minerals are most abundant in the ground and in man. Make a diagram illustrating how these minerals move from the earth to man and back again to complete their cycle. Do these minerals contain some of the same elements found in water and carbon dioxide?

D. Equipment: (to be obtained from a pet store) small plastic bag used to carry goldfish, water from a fish tank to fill the bag 3/4 full, 2 - 3 small water snails, few sprigs of water plants on which snails feed, jar to support the plastic bag.

Activity: Place the bag in the jar and put it in light, but not direct sunlight. Put the snails and plants in the water. Fold the top of the bag over and seal it with tape. You now have a special kind of aquarium which is water tight and airtight. Only energy passes through in the form of sunlight. If, however, the plants and animals are healthy, they should survive for several weeks.

Explain how the water cycle, carbon dioxide cycle, and mineral cycle are operating to maintain life in the aquarium.

E. Activity: Describe a food chain found in one of these communities: grassland, artic land, or desert community. You can do this by learning about the food habits of some of the animals found in each community.

F. Activity: Describe the food chain which exists in your plastic bag aquarium.

G. Equipment: small flowerpot, soil, small clean bottle and stopper, four washed grapes

Activity: Put two grapes in the bottle and insert the stopper. Put the other two grapes in some soil in the flowerpot. Sprinkle more soil on the top and water it. Place the pot and bottle on the window sill and leave them for at least a week. Dig up the grapes in the flower pot and observe the remains. Compare them with those in the bottle.

You should find very little of the grapes in the pot. All the rest of the material was decomposed by bacteria and fungi and dissolve in the soil. In the process, some carbon dioxide and water have passed into the air and some minerals have been added to the soil. The same thing happens to every living thing that dies and rots in the earth.

2. ORGANISMS MOVE INTO AND OUT OF THEIR IMMEDIATE ENVIRONMENT, BUT EVENTUALLY THESE ENVIRONMENTS REACH A STATE OF BALANCE.

Background: The balance which exists in nature is the end result of many gradual changes in the environments. It is a relatively stable balance, but not unchanging. Within each environment individual populations are constantly changing in size. An entire group may enter or leave the environment, such as migrating birds, and thus change the balance. Physical factors such as weather and disease often disturb the balance but, if succession (reproduction) continues, a new state of balance will be reached.

A. Activity: Examine this simple chart which shows the balance existing between rabbits and their food supply and the effects of weather conditions upon it.

Let us assume that each rabbit requires one plant to supply its food for the year.

	# of Rabbits	# of Plants	Weather	Conditions and Predictions
1.	50	50	Normal	balance, should remain the same
2.	50	50	Dry	balance, # of plants should decrease
3.	50	40	Normal	disbalance, # of rabbits should decrease
4.	40	45	Normal	disbalance, # of rabbits increase

Continue this chart for a few years with varying weather conditions.

Can you think of any other factors besides weather that can affect the balance between the rabbits and plants? Continue the chart with one or two of these included. Remember the interrelations among all the factors.

B. Equipment: plastic bag aquarium from previous activity

Activity: Observe the activity taking place in the aquarium. If life is still going on, can you say this is a balanced state of existence? If life has stopped, the aquarium is not balanced. Can you find the disbalance and the reason for it?

C. Activity: Find information about one of the following pairs of animals and tell how they are in balance:
1. owls and mice; 2. rabbits and coyotes; 3. small birds and hawks; 4. preying mantises and grasshoppers; 5. ladybird beetles (ladybugs) and cottony cushion scabs (an aphid).

Man has actually helped balance mantises and grasshoppers. Can you see why?

Mice could become extinct if it weren't for owls. Can you explain why? (Mice reproduce so quickly they would soon run out of food and starve.)

3. MAN, MORE THAN ANY OTHER FACTOR, HAS CHANGED THE BALANCES EXISTING IN NATURE AND OFTEN ENTIRELY DESTROYED THEM.

A. Activity: Find pictures demonstrating man changing the balance in nature. Be able to explain how the action is producing change, what part of nature is being affected, and any long range effects that will result from the action.

B. Activity: Find information on one of the following animals: condor, heath hen, passenger pigeon, bison, seal, polar bear, Key Deer, and American Ivory-billed Woodpecker. Tell how man has been responsible for the animal's extinction or near-extinction. From your knowledge of the animal's living habits tell how its absence affected the state of balance in its environment.

PART II - DISBALANCE IN NATURE - AN EXAMPLE

1. WHEN THE COMPOSITION OF AIR IS CHANGED BY THE ADDITION OF SUBSTANCES THAT ARE HARMFUL TO LIVING THINGS, THE AIR IS SAID TO BE POLLUTED. THE SUBSTANCES ARE CALLED POLLUTANTS.

   A. Activity: Make a chart showing the gases found in air and the amount of each gas present. Show the use (uses) of each one.

   B. Activity: The average person inhales approximately 8 liters of air per minute; each liter weighs about 1.2 grams (1 liter = 1.1 quart, 1 pound = 454 grams)

   What is the weight of air inhaled in one minute? (9.6 grams)
   What is the weight and volume inhaled in one hour? (576 grams, 480 liters)
   What is the weight and volume inhaled in one day? (13,824 grams, 30.4 lbs., 11520 liters - 12,672 qts.)

2. ALTHOUGH AIR MAY BE POLLUTED BY NATURAL EVENTS (e.g. DUST STORMS, VOLCANIC ERUPTIONS AND FOREST FIRES), MOST POLLUTANTS ARE THE RESULT OF MAN'S ACTIVITIES.

   Background: Probably the most important producer of air pollutants is the burning of combustible materials. Besides carbon dioxide, CO_2, and water vapor, which are the usual products of combustion, gases, such as carbon monoxide and sulfur dioxide, are often produced when coal burns. Because carbon monoxide-CO and sulfur dioxide - SO_2 are poisonous to most organisms, they can cause serious air pollution problems.

TYPES OF POLLUTANTS IN THE AIR

Percent of Pollutants

- Carbon Monoxide
- sulfur dioxide
- unburned carbon
- dust and soot
- nitrogen oxide
- others

SOURCES OF CARBON MONOXIDE IN AIR

Percent of Source

- motor vehicles
- industrial processes
- generating electricity
- heating systems
- burning of refuses

A. Activity: Looking at the formulas for carbon dioxide, CO_2, and carbon monoxide, CO, explain why, when insufficient oxygen is supplied to a fuel, large amounts of carbon monoxide and smoke are formed. What are the usual by-products of combustion?

This can be demonstrated by gently blowing at a lit candle. The CO_2 from your breath pushes aside the pure oxygen. Notice the resulting smoke.

B. Activity: Learn how carbon monoxide affects human beings.

C. Activity: Use this information to solve the following problems. A moving automobile discharges exhaust fumes containing one pound of carbon monoxide for every eight miles it travels. One pound of CO occupies a volume of 14 cubic feet.

1. Check the odometer on your family car and calculate the weight and volume of CO it has discharged.

2. If either of your parents drives to work calculate the amount of CO discharged daily.

3. Count the cars parked in a particular place (e.g. school parking lot, Redstone Shopping Center, Stoneham Center, Stoneham Square, etc.) and estimate the CO they will discharge while driving through Stoneham. Remember to calculate the mileage through the city.

D. Equipment: candle, matches, alcohol lamps, three clean test tubes of the same size, test tube holder, test tube rack

Activity: Find out which type of flame produces the most soot--candle, match or alcohol. Label the test tubes A, B, and C. Hold test tube A in the candle flame for ten seconds and place it in the rack. Repeat the process using test tube B and the match flame, then test tube C and the alcohol flame. When the test tubes have cooled, examine them for soot deposits. Which flame produced the most? What is soot? Try to explain the results.

3. THE SIZE OF POLLUTANT PARTICLES HELPS DETERMINE HOW LONG THEY WILL REMAIN SUSPENDED IN THE AIR.

Background: Because of their extremely small size, pollutants are measured in a unit of length called the micron. A micron equals 1/10,000 of a centimeter or about 1/25,000 of an inch. Usually particles that are larger than 40 microns in diameter will settle out of the air quite rapidly. They may cause property damage but are too large to be inhaled into the lungs. Smaller particles, however, settle at a much slower rate. In still air, a dust particle 20 microns in diameter will fall about 3,600 centimeters (about 1,400 inches) each hour, but a very small smoke particle with a diameter of .3 micron

will settle at a rate of about 2 centimeters (.8 inxh) each hour. Particles smaller than ten microns can readily be inhaled into the lungs and are important air pollutants.

Here are some size ranges of typical particles found in the air.

Type of Particle	Diameter in Microns	Type	Diameter
raindrops	500-5,000	ash from coal furnaces	3-80
sand	200-2,000	natural fog	1-40
pollen grains	20-60	silica dust from mines	0.5-10
pulverized coal	10-400	chemical fumes	0.5-10
cement dust	10-150	carbon smoke	0.1-1
plant spores	10-30	tobacco smoke	0.01-0.25

A. Activity: Use the information presented above to devise problems such as this: If a dust particle having a diameter of 20 microns and a smoke particle having a diameter of .3 micron are both released from a smokestack 250 feet high, how long will it take each particle to reach the ground? (answers 2 hr.9min. for dust; 3,750 hrs. for smoke)

B. Activity: Learn the types and locations of industries near and around Stoneham and the kinds of pollutants they would emit. Speculate on those that would be most dangerous and why.

4. THROUGH EQUAL AMOUNTS OF POLLUTANT MATERIAL MAY BE DISCHARGED INTO THE ATMOSPHERE DAILY, THE AMOUNT OF NOTICEABLE AIR POLLUTION DEPENDS GREATLY ON THE WEATHER, AND IT, IN TURN, HAS A DEFINITE EFFECT ON WEATHER CONDITIONS.

Background: Wind and topography, quite maturally, play an important role in determing the rate at which pollutants are dispensed. The temperature, also, plays an important role. When the warmest air currents are near the earth they tend to rise into the cooler air above, creating strong updrafts that assist in dispersing pollutants. Occasionally, however, the temperature increases with altitude. This condition is called an inversion. Pollutants discharged into the cooler, heavier air near the ground have a tendency to accumulate there because this air does not rise. As a result, if there is little or no wind blowing, a layer of highly polluted air may form over the area. Inversions can be quite troublesome when they form in valleys with dense populations.

Air masses, caused by unequal heating of the earth's surface, often affect the dispersal of pollutants. Cold air masses, which are heavy, travel close to the earth bringing in clean air and dispersing pollutants. Warm air masses, however, travel over the surface air resulting in very little up-and-down air movement.

Polluted air, in turn, has noticeable effects on weather conditions. Fog droplets form when tiny particles of smoke, sulfuric acid mist, and other pollutants attract molecules of water vapor in the air. The water vapor condenses on these particles forming fog. When heavy smoke and fog are present at the same time, the result is a condition known as smog. A layer of dense haze may absorb as much as 90 percent of the sunlight in an area, preventing ultraviolet rays from reaching the earth's surface.

A. Activity: Examine a physical-political map of the United States and label areas of possible pollution problems. Explain your reasons for choosing these areas.

Then examine a weather map of the U.S. along with your selected "trouble spots." Explain any changes you might make and reasons for them.

B. Activity: Locate the Meuse River Valley (in Belgium), Great Britain, Los Angeles, California, and Donora, Pennsylvania on a physical map. Explain why these locations present pollution problems. Try to find information about experiences each area has had in the past.

C. Equipment: heat radiating device (e.g. strong flashlight, small blower-type heater), two candles and holders

Activity: Attempt to create an air inversion. Set up the heating unit about 12 inches above one candle. Place the other candle out of its range. Light both candles and gently blow at them to create smoke. If an inversion has been created what should happen to the air in it? Observe both set-ups carefully and explain the differences.

5. MANY POLLUTANTS IN THE AIR ARE KNOWN TO HAVE HARMFUL EFFECTS ON LIVING THINGS.

Background: Heart disease, lung cancer, and eye, nose and throat irritations may all result from air pollution. Sulfur dioxide, combined with carbon dioxide and water vapor, has a damaging effect on trees, leafy vegetable crops, and many grain plants. Pollutants that accumulate in plants are often eaten by animals, which are in turn, poisoned. Tiny pollutants often clog stomata, thus retarding photosynthesis and plant growth.

A. Equipment: small magnifying lens, plant samples from land very close to highway and further off the road.

Activity: Use the magnifying lens to examine individual leaves from each plant. Note the color, size and surfaces of each specimen and explain any differences you can find.

B. Equipment: two similar plants

Activity: Place one plant in an area of clean clear air (if you can find such a place) and put the other in a polluted area (e.g. near a rubbish burner, factory smokestack, busy highway intersection). Raise the plants in those locations for at least one week and compare the results. Be sure all other factors-sunlight, water, soil, are equal.

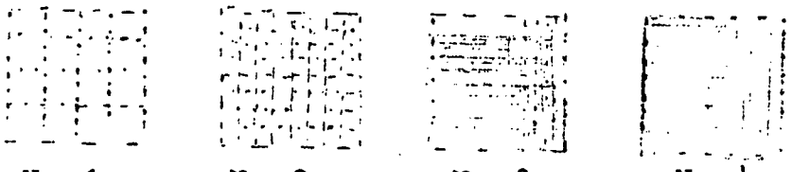
C. Activity: Discuss ways in which the effects of air pollution can disrupt and change the balance in nature. Try to dramatize specific cases, e.g. a chemical factory is built next to a dairy farm in a valley.

D. Activity: Obtain information on the following diseases: emphysema, bronchial asthma, and lung cancer. How are air pollution and smoking related to these diseases?

6. SPECIAL METHODS HAVE BEEN DEVELOPED TO MEASURE THE AMOUNTS OF DIFFERENT KINDS OF AIR POLLUTANTS.

Background: A Ringelmann Chart consists of a series of grids composed of black lines ruled on a white background. When viewed at arm's length, the grids appear as graduated shades of gray that vary between all white and all black. Each shade represents a certain smoke density which, when matched with smoke in the air, helps determine its density.

Dustfall measurements, taken in many communities, help determine the amount, kind, and location of pollutants in the area. Jars containing distilled water are placed on low, flat roofs at several locations for one month periods after which the dusfall is collected and analyzed. Results are expressed in tons per square mile per month. Urban deposits may amount to 300 tons while rural areas may have only 5 tons per month in a square mile.



No. 1 20% smoke density | No. 2 40% | No. 3 60% | No. 4 80%

Example of Ringelmann Chart

A. Equipment: two glass plates of equal size, petroleum jelly, microscope or magnifying glass.

Activity: Cover each plate with a layer of jelly. Place one on an outside window ledge and the other in the classroom where it will not be disturbed. After one day of exposure examine each plate with the magnifying device. Compare the size, color and amount of particles on each plate and explain the differences.

This same measurement device may be used in other places throughout your neighborhoods and city.

B. Activity: Write to the National Center for Air Pollution Control in Cincinnati, Ohio for information on air-sampling stations located throughthe United States.

C. Activity: Interview an employee of the Stoneham Public Works Dept. to obtain information about devices used measure pollution in this area.

7. SINCE NO WAY IS YET KNOWN TO REMOVE POLLUTANTS FROM THE AIR, POLLUTION CAN BE CONTROLLED ONLY BY PREVENTING THEM FROM GETTING INTO THE AIR.

A. Activity: Try to obtain information from local industries about methods or devices they use to prevent air pollution.

B. Activity: Obtain information from the Metropolitan District Commission, 20 Somerset Street, Boston, Mass. 02108, concerning projects underway in the Boston area and/or state of Massachusetts to prevent air pollution.

C. Activity: Check the Stoneham Public Works Dept. for laws pertaining to rubbish disposal or burning. How are such activities connected with air pollution and its prevention?

D. Activity: Learn about air conditioners and their role in preventing air pollution.

Extension Activities

1. Make a list of plants and animals that have been carried into different regions by man. Make a thorough study of one of these organisms and learn where it originated, where it was carried and why, how it adapted to new environments, and how it changed its surroundings.

2. Observe the organisms in a specific environmant, e.g. vacant lot, park, wooded area, shore, etc., and attempt to discover the food web existing among them. Note how the habits of each member and individual patterns relate with others to promote a balanced environment.

3. Man has endangered nature's balance in other ways besides polluting the air. He has jeopardized the water, soil, and land as well. Choose one of these areas and learn how it is being upset, what the effects on the surroundings are, and how man is trying to correct the situation.

APPENDIX

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*Shuttlesworth, Dorothy. Clean Air-Sparkling Water. Doubleday, 1968

* Smith, Frances. The First Book of Conservation. Watts, 1954.

* Webber, Irma. Anywhere in the World. Scott, 1947.

* These books may be found in the Stoneham Public Library.

FILMS

Air Pollution-Everyone's Business	Kaiser	20 min., color
Life in a Cubic Foot of Soil	Coronet	11 min., color
Life in the Woodlot	Nat'l Film Board of Canada	17 min., color
Pond Life	EBF	11 min., b & w
Quetico	Contemporary	22 min., color
The Window	Audubon	17 min., color

FILMSTRIPS

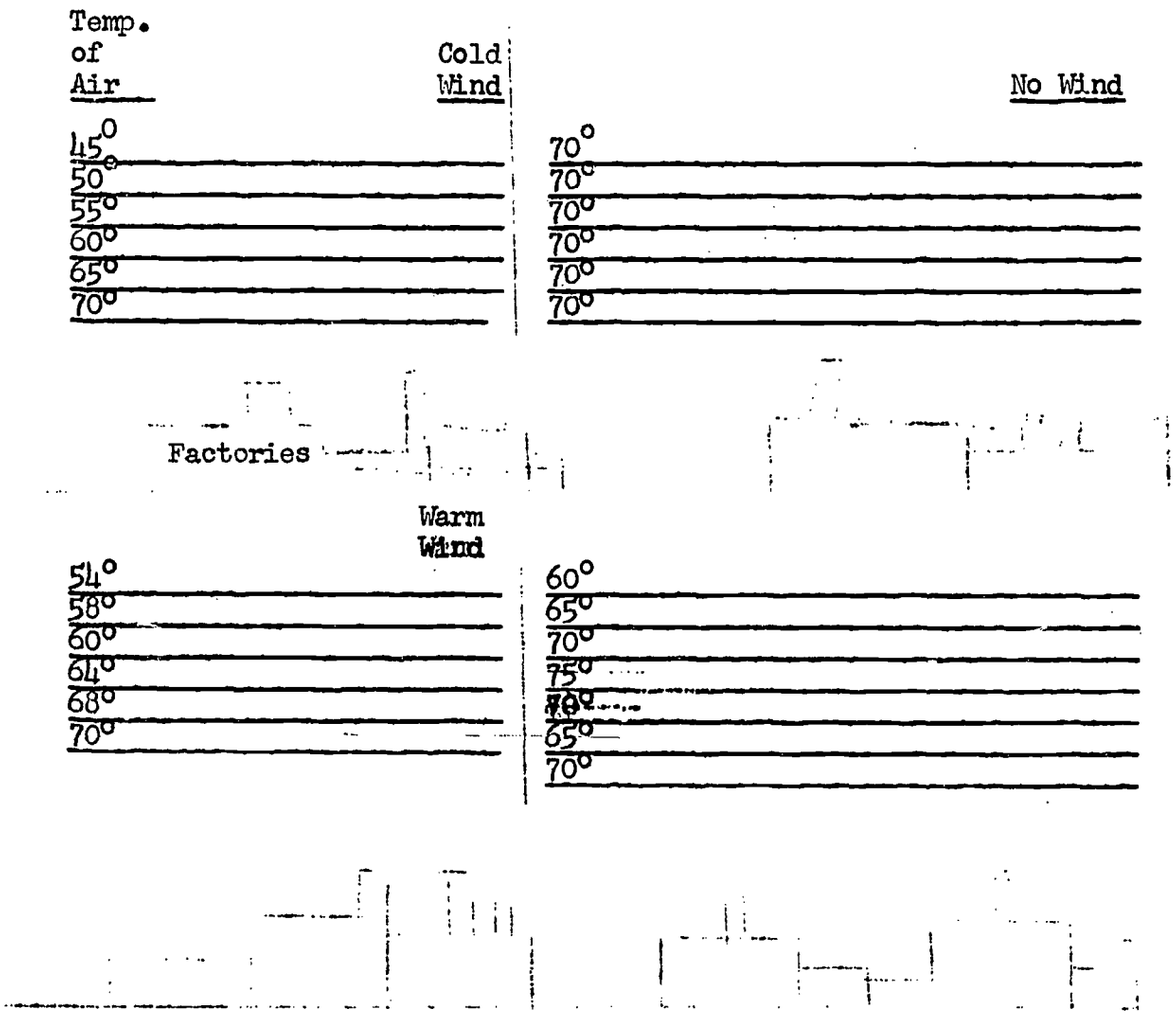
Balance of Nature	Eyegate	color
City as a Community	McGraw	color
Cycle of Nature	Eyegate	color
Fresh Water Ecology	McGraw	color
Introduction to Ecology	McGraw	color
Seacoast Ecology	McGraw	color
What is Conservation	EBF	color

Air and Life	* 3 - 3 - D2
Air in Action	3 - 3 - B5
Animals Affect Man and Other Living Things	3 - 3 - C6
The Field Day-Man Cooperates with Nature	3 - 3 - A6
Living Things Need Other Living Things	3 - 2 - C5
Nature Cooperates with Man: Construction	3 - 3 - A7

* location in supervisor's files.

Worksheet Ideas

On a Clear Day ...?

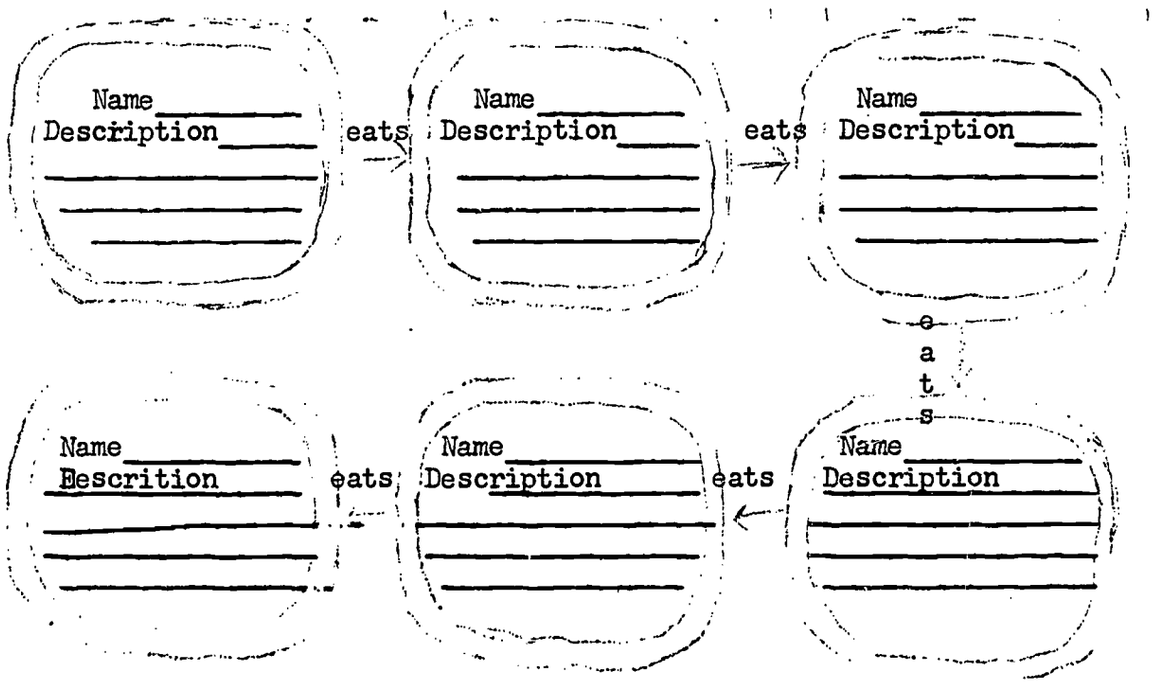


Directions: Show how pollutants would (or would not) be dispersed from the smokestacks in each diagram. Explain each situation.

Links in the Chain

Direction: Use reference books to find information about the animals listed below. Then arrange them properly in the food chain below.

Anchovy, Copepod, Diatom, Mackerel, Shark, Tuna



How is the first link in this chain destroyed?

(answers - Shark → tuna → Mackerel → Anchovy → Copepod → Diatom

Bulletin Board Ideas

Air Pollution in Stoneham - Obtain (or have students make) a large map of Stoneham. On it locate sources of air pollution (e.g. heavily traveled streets with stoplights, factories, centers for rubbish burning, etc.)

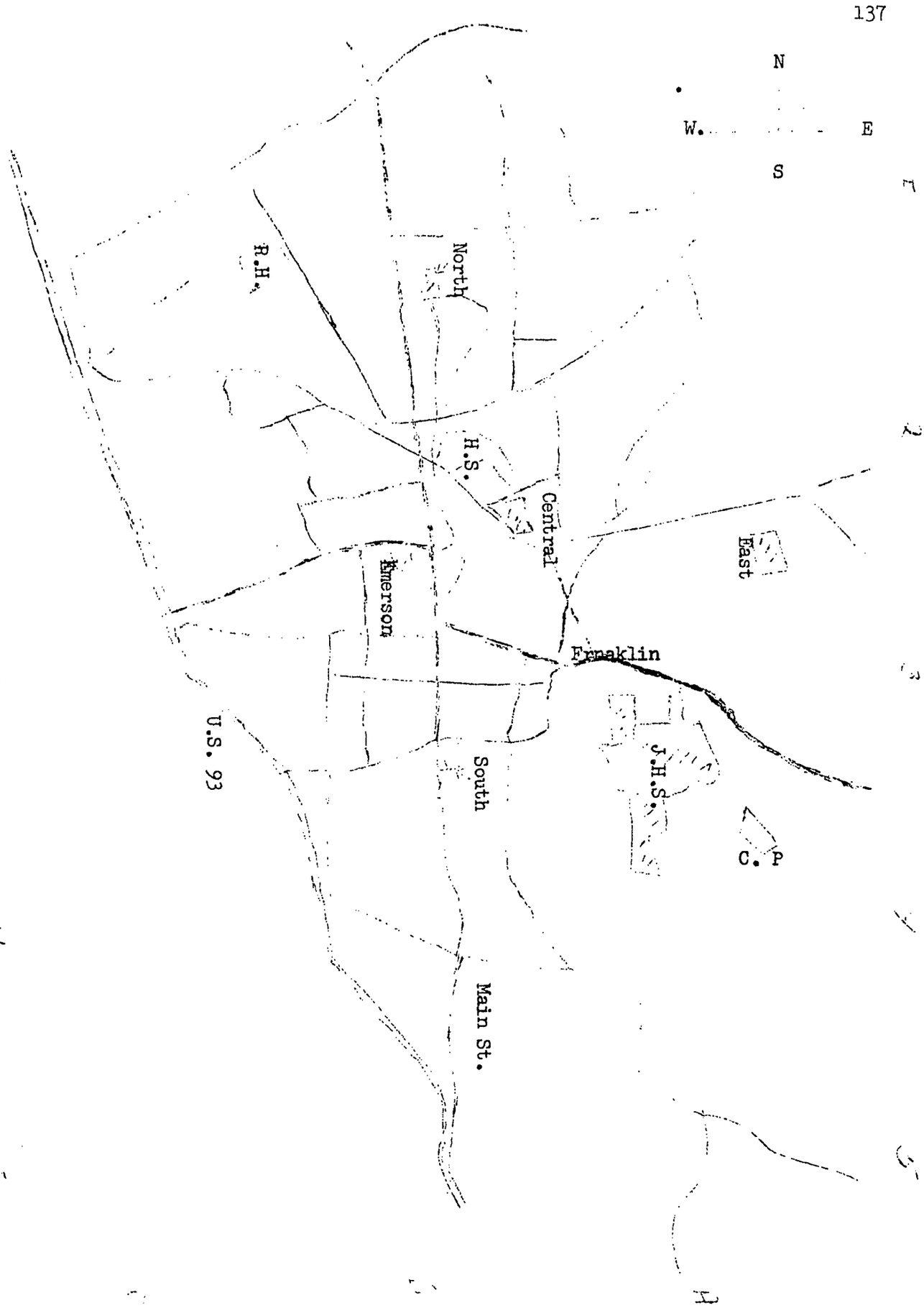
HOW DO THEY WORK TOGETHER?

Sun _____ Air _____

Plants | Animals | Man

_____ Soil _____

Have students use various colors to represent CO_2, O_2, H_2O, energy, and food substances and show how each circulates.



This map of Stoneham (with street names completed by students) may prove useful with activities relating to air pollution in Stoneham.